GUIDELINES FOR THE DESIGN OF SANITARY SEWAGE SYSTEMS

JULY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

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1.0 INTRODUCTION

Par 1 These guidelines are primarily intended to outline minimum acceptable levels of servicing to assist consulting engineers, municipal engineering staff, and other designers in the preparation of sanitary sewage system designs that will meet the approval requirements of the Ministry of the Environment. It should be noted that other approval authorities, such as the municipalities in which the works will be constructed, may have servicing standards that exceed the requirements of these guidelines. The designer should, therefore, ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 2 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to apply where applicable to other sewage systems serving developments such as mobile home parks, condominium, etc. which also require Ministry of the Environment approval under the Ontario Water Resources Act.

Par 3 To allow the guidelines to be more simply modified in future, and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 4 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with, in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health conditions can be safeguarded by alternative approaches, such methods will be considered for approval.

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2.0 SANITARY SEWER SYSTEMS

2.1 SEPARATE vs COMBINED SEWERS

Par 1 All new sewer construction within the Province of Ontario should be of the "separate" type, with all forms of storm and groundwater flow being excluded to the greatest possible extent. New "combined" sewer systems will not be approved. New storm drainage systems will not be permitted to connect to existing "combined" sewers except as an interim measure where circumstances allow no other alternative. In such cases, the proponents will be required to provide the justification for the continued use of combined sewers along with a plan and a timetable for the ultimate disposition of the storm drainage.

2.2 DESIGN PERIOD AND TRIBUTARY AREA

Par 1 Wherever possible, the design of sanitary sewers should be based on the ultimate sewage flows expected from the tributary area. Tributary areas need not necessarily be restricted to current municipal limits. In cases, however, where the tributary area is poorly defined, or where the financial burden on present users would be too severe, the sewage system design may be based on more restricted approaches. In these cases, however, the design period should be at least 20 years.

2.3 DESIGN POPULATIONS AND FUTURE LAND USES

Par 1 For the purposes of estimating future sewage flow rates for municipal sewage collection systems, the designer should make reference to the Official Plan (or Draft Official Plan) of the municipality. Such official plans will contain future population densities and land uses.

Par 2 If no Official Plan, or Draft, exists, the designer should size sanitary sewers for population densities of at least 25 persons per gross hectare. This minimum level of population density will generally be suitable for rural municipalities only. If the municipality already has higher population densities, the designer should use similar, or higher, densities for new growth areas.

2.4 ENERGY REQUIREMENTS

Par 1 In view of the rising cost of energy and the possibility of future energy shortages, designers should attempt to minimize the number of sewage pumping stations required in sewage collection systems. In many instances, deeper gravity sewers, inverted siphons or aerial sewers, may not only eliminate the need for pumping stations, but they may prove to be economically more attractive in the long-term.

Par 2 It is recommended that designers evaluate gravity sewer alternatives to sewage pumping stations by comparing the total of the capital, operating, and maintenance costs of the two approaches. To make such a comparison, it is suggested that all annual costs be expressed as equivalent capital costs.

Par 3 To compensate for future increases in such items as labour and energy costs and to allow for financing interest rates, it is suggested that the present day annual costs be capitalized by multiplying by a factor for labour and a factor for energy related expenses. For a more detailed discussion of this subject and the methods of arriving at the above factors, the reader should make reference to the Ministry publication, "Guidelines for Energy Conservation in the Design of Sewage Systems and Treatment Facilities in the Province of Ontario", August 1977. In addition, local hydro rates should be used in establishing the average cost per kilowatt hour.

Par 4 If, in the review of applications by the Ministry of the Environment, it appears that more cost effective and/or less energy intensive alternatives could have been proposed, the designer may be requested to submit detailed comparisons of the proposal and possible alternatives.

2.5 HYDRAULIC DESIGN

2.5.1 Design Sewage Flows

Par 1 Sanitary sewage flows are made up of waste discharges from residential, commercial, institutional, and industrial establishments, plus extraneous non-waste flow components from such sources as groundwater, and surface runoff.

Par 2 The peak sewage flow rates for which sewer system capacity is to be provided, must be calculated with due consideration being given to all the above-mentioned possible flow contributors, for present and future conditions. In addition to being able to carry the peak flows, sewers must be able to develop sufficient flow velocity to transport the sewage solids, thus avoiding deposition and the development of nuisance conditions under lesser flow conditions.

2.5.1.1 Domestic Sewage Flows

Par 1 The following criteria should be used in determining peak sewage flows for municipal sewer design for residential areas, including single and multiple housing, mobile home parks, etc.

Par 2 For sanitary sewers on private property, which are exempt from the definition of Plumbing in Ontario Regulation 815/84 by Sentence 74 (f)(x), the design may be based upon the fixture unit approach contained in Subsection 4.10 Hydraulic Loads of the Plumbing Code.

a) Design population derived from drainage area and expected maximum population over design period.

b) Average daily domestic flow (exclusive of extraneous flows) of from 225 to 450 L/cap.d.

c) Peak Extraneous Flow (see Section 2.5.1.4 and Appendix A).

d) Peak domestic sewage flows to be calculated by the following equation -

$$Q(d) = \frac{PqM}{86.4} + IA$$

Where $Q(d)$ = Peak domestic sewage flow (including extraneous flows) in L/s.

P = Design population, in thousands.

q = Average daily per capita domestic flow in L/cap.d (exclusive of extraneous flows).

M = Peaking factor (as derived from Harmon Formula

$$M = 1 + \frac{14}{4+P^{0.5}}, \text{ or}$$

Babbitt Formula

$$M = \frac{5}{P^{0.2}}, \text{ or as}$$

determined from flow studies for similar developments in the same municipality). The minimum permissible peaking factor shall be 2.0.

I = Unit of peak extraneous flow, in L/ha. s.

A = Gross tributary area in hectares.

2.5.1.2 Commercial and Institutional Sewage Flows

Par 1 The sewage flows from commercial and institutional establishments vary greatly with the type of water-using facilities present in the development, the population using the facilities, the presence of water metering, the extent of extraneous flows entering the sewers, etc.

Par 2 Institutional flows should be completed in each individual case based on historical records, when available. Where no records are available, the unit values below should be used. For commercial and tourist-commercial areas, a minimum allowance of 28 m^3/ha.d average flow should be used in the absence of reliable flow data.

Par 3 For individual commercial and institutional uses the following sewage flow rates are commonly used for design.

	Sewage Flows* (Avg. Daily)
Shopping Centres	- 2500-5000 L/1000 m^2 day (based on total floor area)
Hospitals	- 900-1800 L/bed. day
Schools	- 70-140 L/student. day
Travel Trailer Parks	- 340 L/space day (minimum without indiv. water hook ups) - 800 L/space day (minimum with indiv. water hook-ups)

Campgrounds - 225-570 L/campsite.day

Mobile Home Parks - 1000 L/space.day

Motels - 150-200 L/bed space.day

Hotels - 225 L/bed space.day

*Unit sewage flow rates exclusive of extraneous flows.

Par 4 The peaking factors applicable for sewage flows from individual establishments will be similar to the peak water usage rates discussed in Section 2.1.1.2 of the "Guidelines for the Design of Water Distribution Systems".

2.5.1.3 Industrial Sewage Flows

Par 1 Peak sewage flow rates from industrial areas vary greatly with the extent of the area, the type(s) of industry present, the provision of in-plant treatment or regulation of flows, the presence of cooling waters in the discharge etc.

Due to the occasional presence of individual industrial water supplies, the rates of water supply from municipal systems into industrial areas will not always be indicative of the sanitary sewage flows to be expected. Conversely, the discharge of good quality cooling water, originally derived from municipal supplies, into storm sewers or surface water courses, may result in lower flows in sanitary sewers than would be expected based on municipal water usage.

Par 2 The calculation of design sewage flow rates for industrial areas is, therefore, difficult. Careful control over the type of industry permitted in new areas is perhaps the most acceptable way to approach the problem. In this way, a reasonable allowance can be made for peak industrial sewage flows for an area and then the industries permitted to locate in the area can be carefully monitored to ensure that the overall allowances are not exceeded. Industries with the potential to discharge sewage at higher than the accepted rate could either be barred from the area, or be required to provide flow equalization and/or off-peak discharge facilities.

Par 3 Some typical sewage flow allowances for industrial areas are 35 m^3/hectare.day for light industry and 55 m^3/hectare.day for heavy industry. These are average flow rates and the peak sewage flow rates vary with the size of the industrial area as shown in Appendix B.

2.5.1.4 Extraneous Sewage Flows

Par 1 When designing sanitary collector sewer systems, an allowance should be made for the leakage of groundwater into the sewers and building sewer connections (infiltration) and for other extraneous water entering the sewers from sources such as manhole covers.

Par 2 Due to the extremely high peak flows that can result from roof downspouts, they should not, in any circumstance, be connected directly, or indirectly via foundation drains, to sanitary sewers.

Par 3 Also, the Ministry of the Environment discourages the connection of foundation drains to new sanitary sewers and in certain circumstances may not condone this practice. Studies which have been conducted by the Ministry show that flows from this source can result in gross overloading of sewers, pumping stations and sewage treatment plants for extended periods of time.

Par 4 Since sanitary sewers are not designed to accept these flows (i.e., rainwater leaders and/or foundation drains), serious damage/problems may result, such as cracking of basement floor slabs or flooding of basements if foundation drainage is discharged to the sanitary sewers. The Ministry recommends that foundation drainage be directed either to the surface of the ground or into a storm sewer system if one exists (refer to MOE Urban Drainage Guidelines for more details on this subject).

Par 5 The amount of groundwater leakage directly into the sewer system (infiltration) will vary with the quality of construction, type of joints, ground conditions, level of groundwater in relation to pipe, etc. Although such infiltration can be reduced by proper design, construction and maintenance, it cannot be completely eliminated and an allowance must be made in the design sewage flows to cover this flow component. Despite the fact that these allowances are generally referred to as infiltration allowances, they are intended to cover the peak extraneous flows from all sources likely to contribute non-waste flows to the sewer system.

Par 6 Appendix A contains examples of typical extraneous flow allowances for acceptance testing of new sewers, sewer design, sewage pumping station and sewage treatment plant design and existing sewer system assessment.

When calculating the extraneous flow component of the peak flow to either a sewage pumping station or a sewage treatment plant for an existing established population centre (Section 2.5.1.1 d)) the IA value should not be used. Rather, an allowance of 90 L/c.d (average) and 227 L/c.d (peak) should be used. For new raw land (i.e., subdivision development) the IA value can be used.

This differentiation is necessary to reflect the substantially lower population densities which inevitably exist in an established unserviced community as compared to those densities found in a new development.

2.5.2 Flow Formula and Roughness Coefficient

Par 1 The Ministry of the Environment recommends that sanitary sewers be designed using either Kutter's or Manning's formula and a roughness coefficient (n) of no lower than 0.013 for all smooth-walled pipe materials.

Par 2 The Manning formula, which is the most commonly used formula for calculating sewer capacity, is as follows:

$$Q = \frac{7.855 \times 10^{-6}}{n} D^{2}.R^{0.67} S^{\frac{1}{2}}$$

Where Q = Flow capacity of sewer (L/s)
D = Inside diameter of pipe (mm)
R = Hydraulic radius of pipe (mm)
S = Sewer slope
n = Kutter or Manning roughness coefficient

Par 3 For small diameter sewers (i.e., less than 900 mm), Kutter's formula gives a more conservative estimate of sewer capacity. For this reason, Kutter's formula is usually used to calculate minimum acceptable sewer slopes (see Section 2.5.4).

2.5.3 Minimum and Maximum Velocities

Par 1 All sewers should be designed with such slopes that they will achieve a mean sewage flow velocity, when flowing full, of at least 0.6 m/s. In cases where the flow depth in the sewer, under peak flow, will not be 0.3 of the diameter or greater, the actual peak flow velocity should be calculated using a hydraulic-elements chart and the slope increased to achieve adequate flushing velocities. In certain circumstances, such as where increased slopes would require deepening of extensive sections of the sewage collection system or the addition of a pumping station, peak sewage flow velocities of less than 0.6 m/s may be acceptable provided that the municipality accepts that there may be increased maintenance requirements.

Par 2 It should be remembered that sewers achieving flow velocities less than those required for self-cleansing of grit and organics may have increased maintenance expenses due to the deposition of solids and need for frequent cleaning. These increased maintenance costs should be compared with the costs which would have been incurred if sewers were deepened to achieve adequate slopes.

Par 3 In sizing sanitary sewers and selecting sewer slopes, consideration must be given to possible sulphide generation problems. Sulphide problems can be minimized by designing for sewers to flow less than full under peak flow conditions and to flow at velocities of 0.6 m/s, or more. Reference should be made to the EPA publication "Sulphide Control in Sanitary Sewerage Systems" or "Control of Sulphides in Sewerage Systems" by D.K.B. Thistlethwayte for more information.

Par 4 The velocities in sanitary sewer systems should not be more than 3 m/s, especially where high grit loads are expected. Higher velocities should be avoided unless special precautions are taken to protect against pipe displacement and pipe erosion.

2.5.4 Minimum Sewer Slopes

Par 1 All sewers should be designed and constructed to give minimum velocities, when flowing full, of not less than 0.6 m/s, based on Kutter's formula using an "n" value of 0.013. The following are the minimum slopes which should be provided:

Sewer Size	Minimum Slope in Metres per 100 Metres
NPS-6	0.52 (see item 2.6.1)
NPS-8	0.40
NPS-10	0.28
NPS-12	0.22
NPS-14	0.17
NPS-15	0.15
NPS-16	0.14
NPS-18	0.12
NPS-21	0.10
NPS-24	0.08
NPS-27	0.067
NPS-30	0.058
NPS-36	0.046

NOTE: Nominal pipe size is indicated by an NPS designation number. The designation number is the nominal inch size of the pipe and follows the nomenclature in CSA B182 Series Standards.

Par 2 Slopes less than those required for 0.6 m/s velocity when flowing full may be permitted when increasing of the slope would require deepening of extensive sections of the system or the addition of a pumping station. In such instances, the reduction of slope would only apply to NPS-8 and NPS-10 pipe and the minimum allowable slope would be 0.28% for NPS-8 pipe and 0.22% for NPS-10 pipe.

2.5.5 Allowances for Hydraulic Losses at Sewer Manholes

Par 1 The following minimum allowances should be made for hydraulic losses incurred at sewer manholes:

a)	straight run	Grade of sewer
b)	45° turn	0.03 m
c)	90° turn	0.06 m
d)	Junctions and transitions	See Appendix D

Par 2 Although the above invert drops will be adequate for sewers flowing at velocities at the low end of the acceptable range, the required drops should be calculated for high velocity sewers.

2.5.6 Design Calculations

Par 1 When submitting applications to the Ministry of the Environment for approval, they should be accompanied by sewer design calculations presenting in tabular form the required capacity, sewer size, sewer slope, roughness coefficient used, pipe capacity provided, flow velocity when flowing full, and depth of flow and actual flow velocity at peak flow if depth of flow is less than 0.3 of the pipe diameter.

Par 2 A typical sewer design sheet is shown in Appendix C.

2.6 SEWER SYSTEM LAYOUT

Par 1 For general discussions of sanitary sewer layout techniques, the designer should refer to such design manuals and texts as the following:

a) "Design Manual for Sewers and Watermains" - sponsored by the Municipal Engineers Association and the Ministry of the Environment.

b) "Design and Construction of Sanitary and Storm Sewers", WPCF Manual of Practice No. 9.

c) "Gravity Sanitary Sewer Design and Construction" WPCF MOP FD-5.

d) "Wastewater Systems - Pipes and Piping" Manual of Practice No. 3, Water and Wastes Engineering.

Par 2 Some aspects of sewer system layout are discussed in the following sections. Since the specific requirements of the municipalities may exceed the guidelines of the Ministry of the Environment, the designer should become acquainted with municipal standards as well.

2.6.1 Minimum Sewer Sizes

Par 1 To facilitate future maintenance and cleaning, the Ministry recommends that a minimum NPS-8 sewer be used in a municipal sanitary sewage collection system. Sanitary sewers which are constructed on private property and which are exempt from the definition of Plumbing in Ontario Regulation 815/84 by Sentence 74(f)(x) may be as small as NPS-6. However, these private sewers must be laid at a minimum grade of 0.52% and should serve no more than 25 private residences or equivalent, based on a fixture unit design.

Par 2 Individual service connections as small as NPS-4 are acceptable.

Par 3 Curvilinear sewers are permitted for sewers with diameters greater than NPS-24, provided the operating authority has equipment to clean such sewer systems.

2.6.2 Depth of Cover

Par 1 In general, sanitary sewers should be laid at sufficient depth to receive sewage from basements by gravity drainage and to prevent freezing and damage due to frost. For buildings substantially below street level, however, it will usually be more economical to pump from these buildings into the sewer rather than deepen the sewer to accomodate a limited number of low lying properties. To allow for gravity drainage from basements, sewer inverts must normally be at least 0.9 to 1.5 m below basement floor levels.

Par 2 Reference should be made to Appendix E for the recommended approach for calculating frost penetration depths.

Par 3 Other factors which can affect sewer depth requirements are interference with other utilities at crossings (both main sewer and building sewer vertical alignments can be affected by storm sewers, watermains, gas mains, etc.) and length of building sewer connections.

2.6.3 Sewer Location

Par 1 Sanitary sewers are generally located at or near the centreline of roads to allow buildings on both sides of the street to be serviced with approximately the same lengths of building sewers. Municipalities generally have standards relating to the preferred location of services. These standards will be acceptable to the Ministry provided that they do no conflict with Ministry Policy No. 08-02-01 pertaining to the separation of sewers and watermains (see Appendix F).

2.6.4 Manhole Spacing

Par 1 Experience with maintenance and repair operations has shown that the acceptable spacing for manholes is 90 to 120 m for sewers NPS-8 to NPS-18 in diameter, and for sewers NPS-20 to NPS-30 in diameter spacings of up to 150 m may be used. Larger sewers may use greater manhole spacing.

Par 2 For any particular municipality, the acceptable manhole spacing will vary depending upon the sewer cleaning equipment available. Some municipalities may require shorter spacing intervals. The above limits may, therefore, be exceeded provided the applicant can demonstrate the suitability of equipment available to handle such spacing.

Par 3 Manholes should be located at all junctions, changes in grade, size, or alignment (except with curvilinear sewers), and termination points of sewers.

Par 4 See Section 2.8.1 for other manhole design guidelines.

2.7 PIPE DESIGN

2.7.1 Pipe Strength Requirements

Par 1 Sewer pipe selected for any particular application must be able to withstand, with an adequate margin of safety, all the combinations of loading conditions to which it is likely to be exposed.

Par 2 Pipe used in gravity flow sewers is usually not subjected to internal pressure, except to a small degree under conditions of surcharge. Therefore, in the design of sewer pipe, internal pressure is usually not a significant factor. In special cases, involving excessive surcharge, such as in inverted siphons, pressure pipe may be required, (Reference should be made to Section 4.0, Pipe Design, of the "Guidelines for the Design of Water Distribution Systems").

Par 3 On the other hand, sewer pipe installed in a backfilled trench carries the external static, live and hydraulic loads placed on it. The factor of external load is, therefore, very important in the design of sewer pipe, regardless of the material used.

Par 4 The design procedures to be used to calculate earth loading, superimposed loads, and the supporting strength of sewer pipe under various types of installations and bedding conditions are well covered in a number of design manuals, texts, pipe supplier's catalogues, etc. A list of some of the better known references follows:

a) "Concrete Pipe Design Manual", American Concrete Pipe Association.

b) "Handbook of Steel Drainage and Highway Construction Products", American Iron and Steel Institute.

c) "Plastic Pipe in Sanitary Engineering", by Lars-Eric Janson, Celanese Piping Systems.

d) Pipe supplier's catalogues.

e) Design and Construction of Sanitary and Storm Sewers "WPCF Manual of Practice No. 9".

f) Water Pollution Control Federation, Manual of Practice FD5.

Par 5 Recent studies have shown that the penetration of frost into the ground causes increases in the earth load on buried pipes. These studies indicated that earth loads roughly doubled despite the fact that the frost penetration did not reach the crown of the pipe. The earth loadings prior to frost penetration were approximately equivalent to calculated prism loads. In these experiments, it is interesting to note that the loading increased to double the normal earth load as the frost penetration increased, but the closest that the frost layer came to the pipes was 0.22 m. It is, therefore, possible that higher loadings would occur if the frost penetrated closer to the pipe.

Par 6 These increased external loads caused by frost may cause beam breaks or other failures in the pipe. This points to the need for proper attention to the installation of the pipe, the selection of pipe materials, pipe strength, bedding types and the proper compaction of the pipe bedding to the springline (see Appendix O).

Par 7 For plastic gravity sewer pipe, the designer is referred to Appendix G, where the Ministry's policy and guidelines for use of such pipe are outlined. All plastic gravity flow sewer pipe installed in Ontario must be designed in accordance with this policy. The only exception in this regard is ABS composite wall sewer pipe for which deflection is limited to a maximum of 3%.

2.7.2 Alternate Pipe Materials

Par 1 The acceptable alternate pipe materials for sanitary sewer systems are as follows:

a) Asbestos-cement
b) ABS Composite Wall
c) Concrete
d) Polyethylene (PE) CGSB 41-GP-23M
e) Polyvinyl Chloride (PVC) Resin Class 12454 B & 12454 C
f) Vitrified Clay

Par 2 In special circumstances, other materials such as ductile iron and steel may also be used, but since their use is relatively limited, they will not be covered in these guidelines.

Par 3 Pipe utilized for gravity sewer systems shall have been manufactured in conformity with the latest acceptable standards issued by the Canadian Standards Association, the American

Society for Testing Materials, or other recognized standards writing organization. Reference should be made to the Ontario Provincial Standard Specification for the accepted standards for pipe, joints and fittings manufacture, bedding and cover materials, etc.

Par 4 For sewer applications requiring pressure pipe, reference should be made to Section 4.0, Pipe Design, of the "Guidelines for the Design of Water Distribution Systems".

Par 5 In choosing a pipe material, the designer should consider the following factors:

a) Life expectancy and use experience;
b) Resistance to scour;
c) Resistance to acids, alkalis, gases, solvents, etc.;
d) Ease of handling and installation;
e) Physical strength;
f) Type of joint - watertightness and ease of assembly;
g) Availability and ease of installation of fittings and connections;
h) Availability in sizes required; and
i) Cost of materials, handling, and installation.

2.8 SEWER APPURTENANCES

2.8.1 Manholes

Par 1 Manholes should be provided on sewer systems at the locations discussed in Section 2.6.4.

Par 2 Reference should be made to the Ontario Provincial Standard Specification for the recommended standards for manholes. Manhole design should be as follows:

a) Minimum Diameter - In general 1200 mm or sewer diameter plus 600 mm whichever is greater, for sewers up to 1050 m. "T" manholes may be used for sewers 1200 mm and larger.

b) Drop Manholes - Should be used where invert levels of inlet and outlet sewers differ by 0.9 m or more.

c) Channel and Benching - The channel and depth should be at least to the spring line of the pipe for NPS-8, NPS-10 and NPS- 12 sewers; and at least to three- fourths of the pipe diameter for NPS- 15 and larger sewers. Channels should have a steel trowel finish.

Benching should be at a slope of at least 1:12 and not greater than 1:8. Benching should have a wood float finish.

d) Manhole Bases - Precast bases may be used for manholes up to 9 m deep.

e) Pipe Connections - A flexible joint should be provided on all pipes, within 0.3 m of the outside wall of the manhole. Concrete bedding to solid ground may be used as an alternate approach.

f) Manhole Steps - 400 mm aluminum or galvanized rungs should be provided at a spacing of 300 to 400 mm.

g) Frost Straps - Where required, frost straps should be provided to hold precast manhole sections together. MOE Research Report No. 78 entitled "Prevention of Frost Heave in Manholes" recommends strapping precast manholes where the freezing index exceeds 500 degree C days (see Appendix P). Refer to the MOE Guidelines for Servicing in Areas Subject to Adverse Conditions" for further discussion of this subject.

h) Safety Chains - Should be provided on the downstream side of manholes for sewers larger than NPS-48.

i) Safety Landings - Safety landings shall be as per Ministry of Labour requirements.

j) Watertight Covers - Watertight covers should be used where manholes will be subject to flooding. Where significant sections of sewers are provided with watertight manholes, extended vents may be required for the sewer system to prevent excessive sulphide generation.

2.8.2 Sanitary Sewer Service Connections

Par 1 Reference should be made to the Ontario Provincial Standard Specification for the recommended standards for service connections. The design of sanitary sewer service connections should be as follows:

a) Minimum Diameter (for gravity flow), NPS-4 or pipe size needed to satisfy requirement of the "Plumbing Code" (18).

b) Connection to Main Sewer - Where the size/diameter of the service lateral is equal to or greater than ½ the size/diameter of the main sewer, the connection to the main sewer should be made via a service tee or wye. Where the size/diameter of the service lateral is less than ½ the size/diameter of the main sewer connections may be made via factory made tees strap-on-saddles or other approved saddles.

c) Sanitary Sewer Service Connection Grades
   - Desireable Grade 2%
   - Minimum Grade 1%

d) Materials - Reference should be made to the Ontario Provincial Standard Specification for acceptable alternate materials for services.

e) Service risers from main sewers buried more than 4.0 m should be taken off at an angle not less than 45° from the vertical; moved to the vertical by an appropriate elbow and the vertical section provided with a slide fitting.

Alternatively, where the main sewer depth is greater than 4.0 m, the use of a shallow "local" collector sewer could be considered with service connections made to the shallow sewer.

2.8.3 Slope Anchors

Par 1 Sewers at 20% slopes, or greater, should be anchored securely with concrete blocks, or equal, spaced as follows:

a) Grades 20 to 35% - Not over 11 m centre to centre.

b) Grades 36 to 50% - Not over 7m centre to centre.

c) Grades over 50% - Not over 5 m centre to centre.

2.8.4 Inverted Syphons

Par All inverted syphons should have the following design features:

a) Number of Barrels - minimum of 2 to handle flow variations.

b) Minimum Pipe Size - at least 150 mm

c) Velocity at Design Flow for each barrel - 1 m/s.

d) Uplift Protection - Syphon pipes and chambers, when subject to hydrostatic uplift forces, must have sufficient weight or anchorage to prevent their flotation when empty.

e) Chamber Design - Special attention should be paid to the design of the inlet and outlet chambers on any syphon installation. For details respecting the design of inlet and outlet chambers reference should be made to "Wastewater Engineering: Collection, Treatment, Disposal" by Metcalf and Eddy, Inc. and "WPCF Manual of Practice No. 9 - Design and Construction of Sanitary and Storm Sewers".

f) Maintenance Provisions - Provision should be made at all syphon installations for routine maintenance/flushing of the barrels. These flushing facilities should be located at the inlet end of the syphon.

3.0 SEWAGE PUMPING STATIONS

3.1 STATION CAPACITY

Par 1 Sewage pumping stations should at least be able to pump the expected 10-year peak sewage flows with the largest capacity pump out of operation. (See Section 2.5.1 for the recommended approach for the calculation of peak sewage flows). For a two pump station, each pump should have sufficient capacity to handle the peak flows. For a three pump station, with the largest pump out of operation, the two remaining pumps operating in parallel should be able to pump the peak sewage flows, etc.

Par 2 Sewage pumping stations should at least be designed so that with minor modifications (pumps, motors or impeller changes), they can handle the 20-year peak sewage flow. Economic evaluation may show that there is no saving by initially providing the 10-year capacity, then increasing the capacity at a later date. It is, of course, preferred that the ultimate anticipated peak flows from the tributary area could be handled with the addition of another pump, and/or forcemain, plus other modifications.

Par 3 Appendix H contains design tables which can be used by designers to summarize the design calculations for applications for approval of pumping stations.

3.2 WET WELL/DRY WELL vs SUBMERSIBLE PUMPING STATIONS

Par 1 Both types of pumping stations are acceptable to the Ministry. As pumping and horsepower requirements increase, wet well/dry well type stations may be more economic.

Par 2 The typical efficiencies of the two types of pumping systems, along with capital, operating and maintenance costs should be considered when choosing between the two types of stations.

Par 3 Factory-built wet well/dry well pumping stations are acceptable as an alternative to custom-built wet well/dry well stations. For large horsepower installations, the heat dissipation limitations of factory-built pumping stations may render them unsuitable. In evaluating factory-built versus custom-built options, the following factors should be considered:

a) Capital, operating and maintenance costs;
b) Flexibility with respect to maintenance and pumping capacity increases;
c) Anticipated life of the structures;
d) Delivery times and construction scheduling;
e) Ministry of Labour requirements related to Occupational Health and Safety Act;
f) Requirement for and availability of skilled labour for installation.
g) Local soil conditions (i.e., corrosion)

3.3 PUMPING STATION SITE CONSIDERATIONS

Par 1 To allow for servicing, vehicle access to the wet well, dry well and buildings on site must be provided.

Par 2 If internal combustion engines are to be provided within the station, the requirements of Section 8 of the Environmental Protection Act must be satisfied. A separate Application for "Air" Approval will be necessary. If the isolation from the engine exhaust to the nearest point of impingement is not sufficient to dissipate the air contaminants to within the regulated levels, an exhaust stack may be required.

Par 3 If more than one sewer enters the site, a junction manhole is preferred so that only one inlet to the wet well will be required. Any electrical controls and/or switch gear located outside must be located in a weatherproof enclosure.

3.4 STANDBY POWER

Par 1 The need for standby power at a sewage pumping station will be assessed by the Ministry of the Environment for each pumping station application. To assist in this evaluation, the designer should furnish the information requested in the Ministry's "Guidelines for the Provision of Equipment to Handle Emergency Conditions (power outages) in New Sewage Works in the Province of Ontario"[12]. Appendix I contains the data form from reference [12].

Par 2 If standby power is required, it may be provided by means of an emergency standby generator powered by either a diesel engine, a gasoline engine, or a natural gas engine, or by an auxiliary drive system powered by any of the foregoing primary power sources. In consideration of their superior reliability, diesel engines are recommended. In certain instances, portable generators, portable gasoline or diesel driven pumps, or the provision of an additional hydro feed line may satisfy the Ministry's standby requirements.

Par 3 Whatever the method of providing standby power, it should be capable of powering sufficient pumps to handle the peak sewage flows. If the generator and diesel engine are not sized to simultaneously run the duty and standby pumps, the standby pump should be locked out in standby mode.

Par 4 In certain circumstances, optional approaches may be used to provide the equivalent protection to standby power. For instance, an oversized wet well, trunk sewer or some other form of underground storage may be acceptable.

3.5 PUMPS

3.5.1 System - Head Calculations

Par 1 Applications for approval should be accompanied with system-head calculations and curves for three conditions as follows:

a) C = 120 and low water level in the wet well.

b) C = 130 and median water level over the normal operating range in the wet well.

c) C = 140 and overflow water level in the wet well.

Par 2 Curve (b) should be used to select the pump and motor since this will reflect the normal operating condition. The extreme operating ranges will be given by the intersections of curves (a) and (c) with the selected pump curve. The pump and motor should be able to operate satisfactorily over this full range.(i.e., between (a) and (c))

Par 3 Although it is normal to size pumps and motors for the 10-year peak flows, consideration should be given to how the 20-year and ultimate sewage flow requirements can be handled. These operating points should also be shown on the system-head curves.

3.5.2 Constant Speed vs Variable Speed Pumps

Par 1 In certain instances, such as pumping stations discharging directly to mechanical sewage treatment plants or into other pumping stations, some means of flow pacing may be required. This can be provided by various means, depending upon the degree of flow pacing necessary. If even minor pump surges would have serious effects, variable speed pumps should be used. If minor surges can be tolerated, two-speed pumps or multiple constant speed pumps can be used.

3.5.3 Solids Handling Capacity

Except where grinder pumps are used, pumps shall be capable of passing spheres of at least 62 mm diameter.

3.6 MINISTRY OF THE ENVIRONMENT SPECIFICATIONS

Par 1 A number of specifications have been prepared by the Ministry for use in MOE subsidized/financed projects. These specifications may also prove useful in the design of non-MOE projects. The following is a listing of these specifications relating to sewage pumping stations.

a) "Standard Specification for Factory-Built Underground Sewage Pumping Stations" MOE Spec. No. 1.

b) "Standard Specification for Diesel Generator Sets" MOE Spec. No. 2.

c) "Standard Specification for Submersible Sewage Pumps, Auxiliary Equipment and Controls" MOE Spec. No. 3.

d) "Standard Specification for Dry pit, Non-Clog Vertical Sewage Pumps" MOE Spec. No. 4.

e) "Standard Specification for Magnetic Flow Meters for Water and Sewage Works" MOE Spec. No. 9.

3.7 WET WELLS

Par 1 Wet wells should be designed with the following features:

a) The cross-sectional area of the wet well above the benching should be constant for the full depth of the wet well.

b) The wet well should be benched to prevent solids deposition and to allow the solids to be transported into the zone of influence of the pump suctions. The benching should a least be at a 1:1 slope and extend to within D/2 of the edge of the intake flared elbow (where "D" is the diameter of the mouth of the flared elbow).

c) Access to the wet well should always be from the outside. An access ladder should be provided from the top slab to the service platform, and a separate ladder from the platform to the bottom of the wet well.

d) The opening to the wet well should be no smaller than 750 x 900 mm. The cover should be equipped with a lock and a pry lip. The opening edge should be flush with the vertical wall of the wet well.

e) The opening to the wet well should be on the wall giving access to float controls, bubbler lines, etc., without the necessity of entering the wet well.

f) The requirements of the Ministry of Labour must be satisfied in the design of the wet well (as well as dry well).

g) Wet wells are classified as Class 1, Group D, Division II, Hazardous Location and the requirements of the Ontario Electrical Safety Code, Section 18, must be satisfied for all electrical installations in wet wells, and the equipment must be CSA approved for use in sewage wet wells.

h) A service platform is normally required to allow for equipment servicing and bar screen cleaning (if used).

i) All wet wells should be equipped with a high water level alarm. Where physically possible, an emergency overflow, with adequate capacity to handle peak flows, should be provided to guard against basement flooding in the event of pumping station failure. Details on the high and normal water levels in the receiving watercourse will be required by the Ministry of the Environment. Backwater and/or shut off valving may be required on the overflow. High water alarms should signal a location which is manned on a 24-hour basis.

j) All wet wells must be provided with ventilation. Usually natural ventilation will suffice for most pumping stations. This can be achieved through two (2) 100 mm diameter vent pipes. Vents should be equipped with a gooseneck at the top, extending 900 mm above the top slab of the wet well. The vents should be equipped with an insect screen. One vent pipe should extend down to within 0.3 metres of the crown of the inlet sewer and the other should terminate on the underside of the roof slab.

If the operating authority prefers, a mechanical ventilation system may be used. The ventilating fan should be oriented to blow fresh air into the wet well at a point 900 mm above the alarm level rather than exhaust from the wet well. A separate exit vent, or vents, will be required as described in the paragraph above.

Under no circumstances should wet well vents open into a building or connect with a building ventilation system.

k) Wet well sizing will be influenced by factors such as the volume required for pump cycling; dimensional requirements to avoid turbulence problems; the vertical separation between pump control points; the inlet sewer elevation(s); capacity required between alarm levels and basement flooding and/or overflow elevations; number of, and horizontal spacing between pumps. The minimum plan area of a wet well should be 4.5 m^2 (i.e., 2.4 m Ø or 2.15 m square) however, wet wells should not provide excessive retention times.

For pumping stations equipped with 50 kW or smaller pumps, the wet well should be of sufficient size to allow for a minimum of a 10-minute cycle time for each pump. To achieve this minimum detention time in a 2-pump station using constant speed pumps, the volume in m^3, between pump start and pump stop should be 0.15 times the pumpage rate of one pump, expressed in L/s. For two speed or variable speed pumps, pumps over 50 kW or for other numbers of pumps, the required volume depends upon the operating mode of the pumping units and/or the recommendation of the motor manufacturer.

Float controls should be at least 300 mm vertically and 450 mm horizontally apart and positioned against a wall away from turbulent areas.

To minimize pumping costs and wet well depth, normal high water level (lag pump start elevation) may be permitted to be above the invert of the inlet sewer(s) provided basement flooding and/or solids deposition will not occur. Where these problems cannot be avoided, the high water level (lag pump start elevation) should be approximately 300 mm below the invert of the inlet sewer.

Low water level (pump shut-down) should be at least 300 mm or twice the pump suction diameter (D) above the centre line of the pump volute. The bottom of the wet well should be no more than D/2, nor less than D/3 below the mouth of the flared intake elbow.

l) Divided wet wells should be considered for all pumping stations with capacities in excess of 100 L/s. Provisions should be made to permit the pumping station to continue operating while one portion of the wet well is dewatered for maintenance or modification.

m) The need for, and the type of screening facilities required for pumping stations varies with the characteristics of the sewage and the requirements of the operating authority. For submersible pumping stations, screening may not be required, but for wet well/dry well stations, it is generally accepted practice to provide screening in the form of a basket screen or a removable bar screen. Although basket screens may be cumbersome to remove and empty, they have the advantage of not requiring entry of operating staff into the wet well for cleaning operations. With basket screens, guide rails should be tubular and similar to submersible pump guide rails. Manually cleaned bar screens should be sloped at 60° and have 38 mm clear openings. The vertical sides should be solid. The minimum width should be 600 mm. A drain platform should be provided for screenings.

n) A potable water supply should not be connected to a wet well. If a water source is required for the wet well, it can be provided via a hose connection in the wall of the generator building or via a yard hydrant. All potable water service lines on a sewage pumping station site must be equipped with a CSA approved backflow preventor of the reduced pressure zone type (double check valve type not acceptable) and be installed, field tested, and maintained in accordance with CSA B64.10M.

o) In wet well/dry well installations, the air bubbler line (if used) and sump pump discharge should be raised above the overflow elevation, in either the wet or dry well, and should cross between the wells below the frost line.

3.8 PUMP SUCTION LINES

Par 1 Pump suction lines should be designed with the following features:

a) Inlets consisting of 90° short radius downturned flared elbows;
b) Suction velocities for 20-year, or greater, pumpage requirements, preferably in the low end of the 0.8 to 2.0 m/s range;
c) Flanged wall pipe with water stop collar;
d) Gate valve (flanged);
e) Flanged eccentric reducer;
f) Minimum pipe size of NPS-4.

3.9 PUMP DISCHARGE PIPING

Par 1 Pump discharge piping should be designed with the following features:

a) Velocities, for the 20-year, or greater, pumpage requirements, preferably in the low end of the 0.8 to 4.0 m/s range;
b) Flanged, concentric increaser;
c) Spacer 150 to 300 mm long with one flanged end and one grooved end for victaulic coupling;
d) Elbows (as necessary);
e) Check valve (flanged), preferably horizontally placed;
f) Gate valve (flanged)
g) Flanged double branch elbow (for 2-pump station);
h) Riser pipe;
i) Magnetic or other type of suitable flow meter and recorder (or pump timers for small, constant speed stations where accuracy of flow measurement is not critical - 3 timers minimum, one for each pump and one for pumps operating in parallel).

3.10 DRY WELLS

Par 1 For detailed guidelines reference should be made to the Ministry Specifications mentioned in Section 3.6. Some necessary design features are listed below:

a) Mechanical (forced) ventilation must be provided in accordance with the Ministry of Labour requirements.

b) A sump pump must be provided to discharge any water accumulations from the dry well to the wet well. The use of two sump pumps and a dry well flood alarm is recommended practice;

c) Due to the possibility of flooding, no permanent potable water service should be provided into the dry well;

d) Dehumidification should be provided to protect electrical control equipment from excess moisture;

e) Each pump should be equipped with a time totalizer and provision for manual alteration of the lead pump;

f) A lifting beam complete with permanently attached trolley or hook should be provided directly above the pump/motor assembly at a minimum height of 1.2 m above the motors to facilitate removal of the pump motors.

3.11 FORCEMAINS

Par 1 Forcemains should have the following design features:

a) Velocities should be in the range of 0.8 to 2.5 m/s, with the lower limit being preferred for the initial phase;

b) The forcemain (and station piping) should be checked for its ability to withstand whatever waterhammer pressures may be experienced. If necessary, measures such as double-acting air valves at critical forcemain locations, dumping valves on the discharge header, etc. may be required to avoid dangerous waterhammer conditions;

c) Acceptable forcemain materials include asbestos-cement, ductile iron, HDPE, PVC, steel, concrete, and glass-fibre-reinforced plastic. See Section 4.0 of the "Guidelines for the Design of Water Distribution Systems" for a discussion of pressure pipe design;

d) Forcemains should be a minimum size of NPS-4 except where grinder pumps are used;

e) To allow pumping stations to be by-passed, during emergencies or major modifications, all forcemains should be equipped with a suitably valved connection to permit connection of discharge piping from a portable pump(s). This connection should be located near the pumping station, but on undisturbed ground, away from the excavation zone for the station itself (see Appendix J)

f) Air release valves, suitable for use with sewage, should be positioned at all significant forcemain high points. These should generally be of the low pressure double acting type.

g) In certain instances, to be determined on a case-by-case basis, it may be required by the Ministry that a forcemain be equipped with intermediate line valve and drain facility(s) similar to that shown in Appendix K.

Factors to be considered in an individual assessment will include, but not be limited to, the diameter and length of the forcemain (i.e., volume of forcemain); the location of the forcemain (i.e., local soil conditions and availability of suitable receiving streams); and environmental implications of a forcemain failure and the subsequent impact of a raw sewage discharge.

h) All sewage forcemains should be terminated at the downstream works in such a manner as to preclude the potential for back flow from the receiving works (i.e., STP influent works; waste stabilization pond influent works, junction manhole etc.) in the event of a forcemain failure. In most instances this can be accomplished via the provision of an atmospheric gap at the outlet end of the forcemain.

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13. Standard Specifications:

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b) MOE Spec. No. 2 Diesel Generator Sets;

c) MOE Spec. No. 3, Submersible Sewage Pumps, Auxiliary Equipment and Controls;

d) MOE Spec. No. 4, Dry Pit, Non-Clog, Vertical Sewage Pumps;

e) MOE Spec. No. 9, Magnetic Flow Meters for Water and Sewage Works;

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MINISTRY OF THE ENVIRONMENT

INTERIM
GUIDELINES FOR THE DESIGN OF STORM SEWER SYSTEMS

JULY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

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In 1982 a committee was established to undertake a general revision of the guideline document. The members of this committee were as follows:

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1.0 INTRODUCTION

Par 1 These design guidelines have been prepared to outline the Ministry's current preferences with regard to the design of storm sewer systems. Due to the fact that the extension of combined sewer systems is discouraged by the Ministry, no attempt has been made to cover such systems in this document. These guidelines are interim in nature, since it is anticipated that policy statements will be made in the near future that will change the approach to stormwater management in the Province of Ontario. Final design guidelines will be issued following this policy statement.

Par 2 The guidelines covered in this document represent minimum acceptable levels of servicing that would enable the works to receive approval under the Ontario Water Resources Act. It should be noted that other approval authorities, such as the municipalities in which the works will be constructed may have servicing standards that exceed the requirements of these guidelines. The designer should therefore ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 3 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to apply, where applicable, to other storm sewer systems serving developments such as mobile home parks, condominiums, etc. which also require Ministry of the Environment approval under the Ontario Water Resources Act.

Par 4 Within certain watersheds of Ontario, stormwater treatment is required. The designer should, before initiating a design, contact the Technical Support Section of the Ministry's Regional Office to determine if the watershed has any particular stormwater treatment requirements. These guidelines do not attempt to deal with stormwater treatment.

Par 5 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 6 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with, in order to obtain approval. It is not the intention of the Ministry to stifle innovation. Whenever a designer can demonstrate that environmental and public health considerations can be safeguarded and property protection from flooding damage by alternative approaches, such methods will be considered for approval.

2.0 DESIGN FLOWS

2.1 RUNOFF COMPUTATION

Par 1 The peak rate of runoff from an area can generally be calculated using the Rational Formula:

$$Q = 2.78\ AIR$$

Where Q = Peak flow in L/s
A = Area in hectares
I = Average rainfall intensity in millimetres per hour for a duration equal to the time of concentration for a particular storm frequency
R = Runoff coefficient

Par 2 This formula is useful for sizing storm sewers to remove water as fast as possible from street surfaces for the given design storm. When the volume of run-off or the rate over time (hydrograph) is required then a hydrologic simulation model will be necessary.

Par 3 Calculations based on a hydrologic simulation model will also be acceptable. In fact, with systems serving large areas, or involving treatment and/or storage systems, the use of such a system may be necessary.

Par 4 The remainder of this section will deal only with the Rational Method. Reference should also be made to the MTC Drainage Manual for a further discussion of the Rational Method for storm sewer design. This MTC Manual also covers culvert and open channel design procedures.

2.2 DRAINAGE AREA

Par 1 The drainage area to be used in the design of a storm sewer system should include all those areas which will reasonably or naturally drain to the system.

Par 2 The area term in the Rational Formula represents the total area tributary to the point on the storm sewer system under consideration.

2.3 RAINFALL INTENSITY

Par 1 The rainfall intensity for a particular storm frequency and time of concentration should be determined from intensity - duration - frequency curves applicable for the municipality in which the system is to be constructed.

Par 2 For a discussion of rainfall intensity curves, reference should be made to the Manual of Practice on Urban Drainage and the Municipal Works Design Manual.

2.4 DESIGN STORM FREQUENCY

Par 1 The storm frequency to be used in the design of storm water conveyance systems will vary depending upon the nature of the area being served, the value of the property being protected and the consequences of more intense storms being experienced.

Par 2 The Ministry recommends that the major-minor drainage system approach be utilized for urban drainage for all future development. The minor drainage system (i.e., roof gutters, rainwater beaches, service connections, swales, street gutters, catch basins and storm sewers) accommodates the run-off from more frequent storms up to the design frequency of the system (i.e., 1:2 years; 1:5 years, etc.). Where weepers/ foundation drains are connected to the storm sewers, they should also be designed to capture no more than this amount of run-off to prevent surcharge.

Par 3 The major system (i.e., natural streams and valleys and the man-made streets, swales, channels and ponds) accommodates run-off from less frequent storms such as the 100-year storm or regional flood. A policy statement issued by the Ministry of Natural Resources and the Ministry of Municipal Affairs and Housing entitled "Flood Plain Criteria" divides the Province into three regulatory flood zones. The boundaries of these three zones and the design frequency/flood criteria are contained in Appendix A to that policy.

Par 4 For a discussion of the major-minor drainage system concepts reference should be made to the draft "Urban Drainage Design Guidelines" available from the Ministry of the Environment's Water Resources Branch.

Par 5 Although the level of convenience provided by the minor system is basically a decision of the municipality, or the owner of the system in the case of private systems, it is suggested that at least a 2-year storm should be used for design purposes.

2.5 RUNOFF COEFFICIENTS

Par 1 The following ranges of runoff coefficients are considered reasonable for design purposes:

Asphalt, concrete, roof areas	0.90 - 1.00
Grassed areas, parkland	0.15 - 0.35
Commercial	0.75 - 0.85
Industrial	0.65 - 0.75
Residential:	
Single Family	0.40 - 0.45
Semi-detached	0.45 - 0.60
Row housing, Town housing	0.50 - 0.70
Apartments	0.60 - 0.75
Institutional	0.40 - 0.75

Par 2 It should be noted that the runoff coefficient for any particular type of area should be taken from the upper portion of the above ranges to account for antecedent precipitation conditions when expected runoff is being calculated for high intensity, less frequent storms. The lower end of the range may be used for shorter recurrence interval storms under conditions of moderate to flat slopes and permeable soils.

2.6 TIME OF CONCENTRATION

Par 1 The time of concentration is the time required for flow to reach a particular point in the sewer system from the most remote part of the drainage area. It includes not only the travel time in the sewers, but also the inlet time, or time required to flow overland into the sewer system.

Par 2 Inlet times should be calculated, rather than relying upon arbitrary minimum or maximum times. The calculation, however, must be based upon the overland flow route which will exist when the sewer system has been fully developed to the drainage limit. In the case of single family residential areas, calculations will not be required if a maximum inlet time of 10 minutes has been used.

3.0 SEWER DESIGN*

3.1 FLOW FORMULAE AND ROUGHNESS COEFFICIENTS

Par 1 It is recommended that storm sewer capacities be calculated using the Manning formula with a roughness coefficient (n) of 0.013 for all smooth-walled pipe materials. With corrugated metal pipe, 'n' should be 0.024 for plain pipe, 0.020 for paved invert pipe and 0.013 for fully paved pipe.

3.2 ALLOWABLE FLOW VELOCITIES

Par 1 Minimum - 0.8 m/s
Maximum - 6 m/s

3.3 MINIMUM PIPE SIZES

Par 1

a) Storm Sewers
   - NPS-10

b) Catch basin leads
   Single - NPS-8
   Double - NPS-10

c) Building storm drains and building storm sewers
   - as per requirements of Ontario Building Code.

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* Refer also to "Guidelines for the Design of Sanitary Sewage Systems" for a more complete discussion of hydraulics, pipe design, depth of cover, manhole spacing, pipe anchoring, etc.

3.4 DEPTH OF COVER

Par 1 Although it is not always possible due to the elevations of receiving streams, etc., storm sewers should be placed below the depth of frost penetration. The additional loadings caused by frost should be taken into consideration.

3.5 MANHOLE SPACING

Par 1 At all changes in grade, alignment (except for curvilinear sewers). In addition, manholes should be provided on straight runs at the following intervals.

a) Sewers NPS-10 to NPS-18, line spacing - up to 120 m;
b) Sewers NPS-20 to NPS-30, line spacing - up to 150 m;
c) Sewers larger than NPS-30, line spacing - greater than 150 m.

3.6 MANHOLE DESIGN

Par 1 See "Guidelines for the Design of Sanitary Sewage Systems".

3.7 SEPARATION OF SEWERS FROM POTABLE WATER SYSTEMS

Par 1 Ministry Policy 08-02-01 governs the separation of storm and sanitary sewers from water supply systems. See Appendix F for the requirements of this policy and its related guidelines.

3.8 CATCH BASINS

Par 1

a) Catch basins may be installed with, or without, sumps.

b) Catch basins should be provided at adequate intervals to ensure that the road drainage is able to be intercepted up to the capacity of the storm sewer. The spacing will vary with the road width, grade and crossfall and with the design storm frequency. The spacing will also be affected by the location of pedestrian crossing points, intersections, low points, driveway depressions, etc. In general, for pavement widths up to 9.8 m with two per cent crossfall, the maximum spacing should be as follows:

ROAD GRADIENT	MAXIMUM SPACING
0% to 3%	up to 107 m
3.1% to 4.5 %	up to 91 m
over 4.5%	up to 76 m

Stormwater management systems using inlet control catch basins may use less frequent spacings than those outlined above. In such cases, the designers must justify whatever spacing is used.

c) Catch basin manholes are permitted.

3.9 CURVILINEAR SEWERS

Par 1 Curvilinear sewers are permitted for sewers with diameters greater than NPS-24, provided the operating authority has equipment to clean such sewer systems.

3.10 ACCEPTABLE ALTERNATE SEWER MATERIALS

Par 1 Acceptable alternate storm sewer materials include asbestos cement, vitrified clay, PVC, ABS composite wall, concrete, high density polyethylene and corrugated steel.

If it is anticipated/intended that a grant will be received/applied for from the Ministry of Transportation and Communications for the proposed storm sewers, MTC should be contacted respecting subsidizable alternate materials.

3.11 STORM SEWER GRATINGS

Par 1 The inlets and outlets of piped sections of stormwater management systems which are accessible to the public should be provided with protective devices. As a minimum, it is recommended that inlets and outlets of pipes NPS-24 in diameter, or larger, should be provided with gratings to prevent small children from gaining access to the sewers. Grating bars should be spaced 150 mm apart. For large inlet structures, inclined gratings may be necessary to prevent water pressure from trapping a person against the grating. Such inclines will also tend to make the gratings self cleaning from a debris standpoint.

3.12 DESIGN CALCULATIONS

Par 1 All applications for storm sewer approval must be ccompanied by design calculations. These calculations are generally best presented in a form similar to that shown in Appendix C.

4.0 ROOF DRAINAGE

Par 1 Where lot sizes and surface conditions permit, it is preferable that roof drainage discharge onto the ground surface via splash pads rather than connect directly into the storm sewer system.

Par 2 The connection of roof drainage systems to a sanitary sewer system should not be permitted as the hydraulic capacity of the sanitary sewers and downstream works is not adequate thereby increasing the probability of surcharging and the by-passing of raw sewage. Also, the efficiency/operating costs of the downstream works will be adversely impacted.

5.0 FOUNDATION DRAINAGE

Par 1 The Ministry recommends that foundation drainage be directed either to the surface of the ground or to a storm sewer system, if one exists. However, this decision is at the discretion of the Municipality.

Par 2 In arriving at a decision in this regard, the Municipality should consider the following factors:

a) possibility of storm sewer surcharging;
b) difference in elevation between basement floor slabs and storm sewer obverts;
c) possibility of foundation damage and flooding which could result due to back up into private storm drain;
d) where concerns exist respecting a) or b), but where connection to a storm sewer is still desirable, this connection should be made via a sump pump system.
e) the use of a "third" pipe or foundation drain collector.

Par 3 Where foundation drains are to be connected by gravity to the storm sewers, the designer should consider the following options in order to reduce the probability/frequency of foundation drain surcharging:

a) the use of a higher return frequency in the design of the storm sewer;

b) the construction of a deeper sewer with the depth of sewer being determined/ checked by the hydraulic grade line for surcharged conditions;

c) inlet controls or increased spacing of inlets to prevent water from gaining access to the sewers at a rate greater than the design storm.

NOTE: The designer must recongize that the state-of-the-art of inlet control design has not reached the point where performance can be guaranteed.

Par 4 The connection of foundation drains to a sanitary sewer system is strongly discouraged by the Ministry because of the serious negative impact such connections inevitably have on the sanitary sewerage works system.

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GUIDELINES FOR THE DESIGN OF
WATER DISTRIBUTION SYSTEMS

JULY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

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The initial version of these guidelines was prepared in 1979 with the assistance of the consulting firm of Simcoe Engineering Limited, Pickering, Ontario. A committee including representatives from District, Metropolitan, and Regional Municipalities participated in the development of the initial edition.

In 1982 a committee was established to undertake a general revision of the guideline document. The members of this committee were as follows:

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1.0 INTRODUCTION

Par 1 These guidelines are primarily intended to outline acceptable levels of servicing to assist consulting engineers, municipal engineering staff, and other designers in the preparation of water distribution system designs that will meet the approval requirements of the Ministry of the Environment. It should be noted that other approval authorities, such as the municipality in which the works will be constructed, regional governments, etc., may have servicing standards that are different and/or exceed the requirements of these guidelines. The designer should, therefore, ensure that he is aware of the requirements of all other approving authorities prior to submitting designs for approval.

Par 2 Although some aspects of the guidelines relate only to municipal services, the guidelines are meant to apply where applicable to other systems such as mobile home parks, condominium developments, etc. which also require Ministry of the Environment approval under the Ontario Water Resources Act. For recommendations/guidelines regarding the design of water supply systems servicing 500 or fewer persons, reference should be made to the MOE "Guidelines for the Design of Seasonally Operated Water Supply Systems" and "Guidelines for the Design of Water Supply Systems for Small Residential Developments".

Par 3 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 4 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health concerns can be safeguarded by alternative approaches, such methods will be considered for approval.

2.0 HYDRAULIC DESIGN

2.1 DESIGN WATER DEMANDS

Par 1 Water supply systems should be designed to satisfy the greater of either of the following demands:

a) Maximum day plus fire flow (where fire flow is to be provided); or,
b) Peak rate (maximum hourly demand).

Par 2 The maximum day demand is the average usage rate on the maximum day. The fire flow demand will vary with the size of the municipality (chance of multiple fires at any time) and the nature of development (type of construction materials, building height and area, and density of development). The magnitude of the fire flow allowance is the responsibility of the municipality. The peak rate demand is the short-term demand placed upon the system by usages other than fire fighting. The peak rate demand is usually taken as the average water usage over the maximum hour.

Par 3 Wherever possible, peaking factors based on usage records for the water supply system should be used, but when such records do not exist or are unreliable, factors such as those given in Appendix L may be used.

2.1.1. Unit Consumption Rates

2.1.1.1 Domestic Water Demands

Par 1 Domestic water demands will vary greatly from one municipality to another. Depending upon such factors as presence of service metering, lawn-watering practices, use of bleeders to prevent freezing, water quality, leakage, etc., average daily per capita consumption rates can vary from less than 180 litres to more than 1,500 litres.

Par 2 For design purposes, existing reliable records for average, maximum day and peak rates should be used wherever possible. Otherwise, average daily per capita water demands of 270 to 450 litres are recommended. Minimum rate, maximum day and peak rate factors for system should be in accordance with either existing flow data, if available, or the values shown in Appendix L.

Par 3 Where reliable flow records for an existing distribution system suggest that there is an excessive unaccounted-for average daily demand (i.e., unaccounted-for water in excess of 15%), the existing consumption rates should not be used in the design of an extension etc. Rather, an average value of 270 to 450 L/cap.d should be used and the cause of the unaccounted-for water determined and reduced/eliminated as much as is practical.

2.1.1.2 Commercial and Institutional Water Demands

Par 1 The water demands for commercial and institutional establishments vary greatly with the type of water-using facilities present in the development, the population using the facilities, the presence of metering, etc.

Par 2 Institutional flows should be computed in each individual case based on historical records, where available. Where no records are available, the unit values below should be used. For commercial and tourist-commercial areas, an allowance of 28 m^3/ha.d average flow should be used in the absence of reliable flow data.

Par 3 For individual commercial and institutional uses, the following unit water demands are commonly used.

	Water Usage (Avg. Daily)
Shopping Centres	- 2500-5000 L/1000 m^2.day (based on total floor area)
Hospitals	- 900-1800 L/bed.day
Schools	- 70-140 L/student.day
Travel Trailer Parks	- 340 L/space. day (minimum without individual hook-ups) - 800 L/space. day (minimum with individual hook-ups)

Campgrounds	- 225-570 L/campsite.day
Mobile Home Parks	- 1000 L/space.day
Motels	- 150-200 L/bed space.day
Hotels	- 225 L/bed space.day

Par 4 When using the above unit demands, maximum day and peak rate factors must be developed. For establishments in operation for only a portion of the day, such as schools, shopping plazas, etc., the water usage should also be factored accordingly. For instance, with schools operating for 8 hours per day, the water usage rate will be at an average rate of say 70 L/student.day x 24/8 or 210 L/student.day over the 8-hour period of operation. The water usage will drop to residual usage rates during the remainder of the day. Schools generally do not exhibit large maximum day to average day ratios and a factor of 1.5 will generally cover this variation. For estimation of peak demand rates, an assessment of the water using fixtures is generally necessary and a fixture-unit approach is often used.

Par 5 The peak water usage rates in campgrounds will vary with the type of facilities provided (showers, flush toilets, clothes washers, etc.) and the ratio of these facilities to the number of campsites. A peak rate factor of 4 will generally be adequate, however, and this factor should be applied to the average expected water usage at full occupancy of the campsite.

2.1.1.3 Industrial Water Demands

Par 1 Industrial water demands are often expressed in terms of water requirements per gross hectare of industrial development when the type of industry is unknown (i.e., new industrial parks). These demands will vary greatly with the type of industry, but common allowances for industrial areas range from 35 m^3/gross hectare.day for light industry to 55 m^3/gross hectare.day for heavy industry.

These are average daily demands. Peak usage rates will generally be 2 to 4 times the average usage rate.

Par 2 Wnen the type of industry is known, discussions should be held with representatives of the industry to determine water requirements.

2.1.1.4 Fire Demands

Par 1 The level of fire protection to be provided by a municipally-owned potable water supply system is the decision of the municipality. In general, the minimum fire flow,, as recognized by various fire underwriting groups is 30 L/s and to receive credit, the water system must be simultaneously capable of satisfying the maximum day demand.

Par 2 To estimate the fire flow requirements for a particular structure or area of a municipality, the designer should refer to a guide such as, "Water Supply for Public Fire Protection - A Guide to Recommended Practice, 1981", prepared by Fire Underwriters Survey. See also Appendix N.

Par 3 Reference should be made to Ontario Regulation 730/81 "Fire Code" for further fire related requirements, including inspection, testing, hydrant marking, etc.

2.2 DESIGN PERIOD

Par 1 A 20-year design period is most frequently used for water supply systems. Water distribution systems have useful life expectancies well in excess of 20 years, however, and if it is possible from a financial point of view, longer design periods should be used. Shorter design periods may be acceptable where works are strictly short-term and will undergo replacement in the foreseeable future.

2.3 SYSTEM PRESSURES

2.3.1 Maximum and Minimum Operating Pressures

Par 1 It is generally accepted practice to design water supply and distribution systems such that the normal operating pressure ranges between 350 kPa and 550 kPa under a condition of maximum daily flow.

Par 2 The maximum pressures in the distribution system should, in general, not exceed 700 kPa in order to avoid damage to household hot water tanks, rapid wear of tap washers, unnecessary energy consumption, etc. Where localized areas must have pressures above this level, the homes affected should be provided with individual pressure-reducing valves on their services.

Par 3 The distribution system should be sized so that under maximum hourly demand, the pressures are not less than 275 kPa. Under conditions of simultaneous maximum day and fire flow demands, the pressure should not be less than 140 kPa.

2.3.2 Transient Pressures

Par 1 The distribution piping system must be designed to withstand the maximum operating pressure plus the transient pressures to which it will be subjected. Transient pressures are caused by rapid valve operation, pump start-up and shut-down, power failure, etc. Wherever possible, the design of pumping systems should be such that surges caused by pumping station operations are minimized.

Par 2 As a minimum allowance in the distribution system, it is recommended that the pipe and joint strength be such that it can withstand the maximum operating pressure plus the pressure surge that would be created by instantaneous stoppage of a water column moving at 0.6 m/s. The pressure created by such an event will vary depending upon the diameter, wall thickness and pipe material used in the distribution system.

Par 3 When calculating transient pressures for flexible pipe materials, the designer is cautioned that celerity values given in texts, manufacturer's catalogues and other sources of information are usually for the unrestrained condition. When buried, such pipe materials may exhibit higher effective celerity values and correspondingly higher transient pressures. Celerity values utilized in transient analyses should be increased for such pipe materials for buried conditions. A rule of thumb is to use twice the value calculated from the celerity equation.

2.4 FRICTION FACTORS

Par 1 It is recommended that the following Hazen-Williams "C" values be used for the design of water distribution systems, regardless of material:

Diameter	C-Factor
NPS-6	100
NPS-8/NPS-10	110
NPS-12 - NPS-24	120
Over NPS-24	130

Par 2 The above C-factors are intended to represent those which would be experienced in the long term. In calculating maximum velocities for transient pressure estimations, or for checking pump motor sizes for runout conditions, it is recommended that a C-factor of 140 be used to allow for new pipe conditions.

Par 3 In evaluating existing systems for expansion, the C-factors should be determined by actual field tests, wherever possible.

2.5 DESIGN CALCULATIONS

Par 1 Design calculations in support of the sizing of minor extensions to water distribution systems will often not be required where minimum pipe size requirements have dictated the sizing. Where new systems, or major extensions are proposed, design calculations demonstrating the adequacy of the system/extension should accompany the application.

Par 2 When an existing distribution system which has, or is suspected to have, pressure problems, is to be extended or modified, design calculations will be required to demonstrate the acceptability of the proposed works.

Par 3 If a computer analysis has been carried out on the proposed system, the results of that analysis and the input parameters should be noted on a general plan of the system together with an indication of the name of the program used.

2.6 MINIMUM PIPE SIZES

Par 1 The minimum size of watermains should be NPS-6 except for the following cases:

a) Watermains in systems not required to carry fire flows;

b) Beyond the last hydrant on cul-de-sacs. In this case, pipes as small NPS-1 may be used.

Par 2 In all the above cases, hydraulic calculations should be submitted to demonstrate that the proposed pipe sizes are sufficient to sustain at least the minimum pressures discussed in Section 2.3.1. When the inside diameter of the pipe is less than the nominal size, the actual inside diameter should be used in the hydraulic calculations.

Par 3 For water service connections, the minimum pipe size required is NPS-3/4. Commercial/industrial connection and estate type residential development will generally require larger services. See also Section 5.3.

2.7 WATER SERVICE METERS

Par 1 Whether or not water meters are provided on water service connections is a decision of the owner/operator of the water supply and distribution system. Considerable controversy still exists regarding the effect of water meters on consumption. However, it is the recommendation of the Ministry that all water service connections to all potable water distribution system be metered and that any non-domestic connection must be metered with the exception of:

a) connections made exclusively for/to automatic sprinkler systems;

b) connections made for both domestic and automatic sprinkler systems where only the domestic service line should be metered (i.e., no meter on sprinkler service branch).

3.0 SYSTEM LAYOUT

3.1 GRID DESIGN

Par 1 Wherever possible, water distribution system layouts should be designed to eliminate dead-end sections. Where dead-end mains cannot be avoided, they should be provided with a fire hydrant, blow-off or other acceptable measures taken to prevent problems associated with stagnation.

3.2 VALVE PLACEMENT

Par 1 In grid patterns, intersecting watermains should be equipped with shut-off valves, as follows, to minimize disruption during repairs:

	No. of Valves
'T' intersection	at least 2
Cross intersection	at least 3

Par 2 Air release valves should be placed at all significant high points of the system. Where the need for an automatic air release valve is uncertain, a manual air release valve or hydrant can be initially installed and later replaced with an automatic valve, if significant air accumulations are found.

Par 3 With large diameter mains, drain valves positioned at low points may also be required to permit main repairs. Small diameter watermains can generally be drained through hydrants by using compressed air and/or pumping.

3.3 HYDRANT REQUIREMENTS

Par 1 Whether or not fire protection is provided via the communal potable water system is the decision of the municipality/owner of the system. However, once the decision has been made to provide fire protection via the communal potable water system, the provisions of Ontario Regulation 730-Fire Code should be adhered to. Therefore, the designer should acquaint himself with the municipality's/owner's requirements respecting fire protection and the communal potable water system and the Fire Code.

Par 2 Generally, the required hydrant spacing decreases as the fire flow requirement increases. Hydrants must, therefore, be placed much closer together in high risk areas, such as downtown core areas, than in residential areas with detached homes.

Par 3 In residential areas, the line spacing for hydrants is normally recommended to be 120-150 metres. For a more detailed discussion of hydrant spacing requirements reference should be made to "Water Supply for Public Fire Protection - A Guide to Recommended Practice, 1981" and Ontario Regulation 730/81 "Fire Code."

Par 4 Fire hydrants should only be installed on watermains capable of supplying fire flow requirements. The hydrant leads should be NPS-6 diameter pipe.

Par 5 To allow for hydrant maintenance and repair with a minimum of disruption, it is preferred that all hydrant leads be valved.

3.4 DEPTH OF COVER

Par 1 With the exception of those watermains which will be taken out of service and drained in winter, the minimum depth of cover over watermains and service connections, including that portion on private property, should be greater than the depth of frost penetration. On services this depth should be measured to the goose neck when it is vertical.

Par 2 Reference should be made to Appendix E for a recommended method of calculating frost penetration depth.

Par 3 Large diameter watermains, over NPS-12 without service connections, may be installed at such an elevation that the frost-free depth corresponds with the spring line of the pipe rather than the crown.

Par 4 If for economic or practical reasons, it is not possible to install watermains below the frost line, consideration will be given to reduced cover installations provided the design method ensures that the watermain will be unlikely to freeze or be damaged by heaving or increased trench loads caused by frost penetration. Reference should be made to the MOE "Guidelines for Servicing in Adverse Conditions" for details on alternate servicing techniques.

Par 5 Recent studies have shown that the penetration of frost into the ground caused increases in the earth load on buried pipes. These studies indicated that earth loads roughly doubled despite the fact that the frost penetration did not reach the tops of the pipes. The earth loadings prior to frost penetration were approximately equivalent to calculated prism loads. In these experiments, it is interesting to note that the loading increased to double the normal earth load as the frost penetration increased, but the closest that the frost layer came to the pipes was 0.22 metres. It is, therefore, possible that higher loadings would have occurred if the frost had penetrated to the pipe.

Par 6 These increased external loads caused by frost may cause beam breaks in the pipe when bedding is non-uniform. This points to the need for proper attention to the installation of the pipe bedding. It also suggests that great care must be taken in the selection of pipe materials, pipe classes, bedding types and the proper compaction of the bedding to the springline.

3.5 CROSS-CONNECTION CONTROL AND SPACIAL SEPARATION OF WATER AND SEWAGE WORKS

Par 1 Precautions must be taken in the design of water distribution and plumbing systems to preclude the entrance of contaminating materials into the potable water supply.

Par 2 As a general rule, no connection shall be made between a potable water system and a non-potable water system or any potential source of non-potable water or other contaminants.

Par 3 Such contaminants can enter water supply systems from various sources such as cooling water systems, pump seal water systems, industrial process piping, groundwater, etc. To control contamination from non-potable piped systems, cross-connection control measures are necessary. To prevent or minimize the entrance of dangerous contaminants into the water supply from groundwater sources, certain precautions must be taken with respect to the relative location of sewage and water systems.

Par 4 For information on cross connection control equipment, reference should be made to CSA Standard B64.10-M, "Backflow Prevention Devices - Selection, Installation, Maintenance, and Field Testing".

Par 5 The Ministry of the Environment has developed a policy and guidelines covering the separation of sewers and watermains. This policy and the related guidelines are contained in Appendix F.

4.0 PIPE DESIGN

4.1 ALTERNATE PIPE MATERIALS

Par 1 Acceptable alternate materials for watermains are as follows:

a) Asbestos-Cement (AC)
b) Cement Lined-Cement Coated Steel
c) Ductile Iron/cement lined (DI)
d) Glass Fibre Reinforced Plastic
(RTRP & RPMP)
e) High Density Polyethylene (HDPE)
f) Polyvinyl Chloride (See Appendix M)
(PVC - 12454-A & 12454-B)
g) Reinforced Concrete Pressure Pipe

Pipe selected shall have been manufactured in conformity with the latest standards issued by the Canadian Standards Association, the Canadian Government Standards Board, the American Water Works Association, the American Society for Testing Materials, or other recognized standards writing organizations. Reference should be made to the Ontario Provincial Standard Specification for the recommended standards for pipe, joints and fittings manufacture, bedding and cover materials, etc.

Par 2 In selecting a pipe material, the designer should consider the following factors:

a) Costs (capital, operating, maintenance and other costs);
b) Trench foundation conditions;
c) Location;

d) Soil corrosivity;
e) Potable water corrosivity;
f) Available labour skills;
g) Availability of suitable fittings and appurtenances acceptable to/recommended by the manufacturer of the pipe.

4.2 PIPE STRENGTH

Par 1 Section 2.3.1 and 2.3.2 discussed the operating and transient pressures which are experienced in distribution systems. Buried watermains are also subjected to external loads imposed by the trench backfill, frost loading, and superimposed loads (either static or dynamic, or both). The watermain pipe selected for a particular application must be able to withstand, with an adequate margin of safety, all the combinations of loading conditions to which it is likely to be exposed.

Par 2 Pipe strength designations and the methods for selecting the required pipe strength vary with the types of materials used for watermains. For a thorough understanding of this subject, it will be necessary for the designer to evaluate the pipe supplier information and consult such references as the pertinent CSA, ANSI, and AWWA Standards and Design Manuals.

Par 3 The minimum pressure Class/Series requirements for the most commonly used watermain materials shall be Class 50 for Ductile Iron, Class 150 for Asbestos Cement, Class 100 or Series 160 (i.e., DR 25 or SDR 26) for PVC, and Series 80 (DR 18) for HDPE.

5.0 WATERMAIN APPURTENANCES

5.1 HYDRANTS

Par 1 All hydrants used on distribution systems in the Province of Ontario should be of the dry-barrel type to minimize freezing problems. They should be manufactured in accordance with the latest edition of AWWA C502.

Par 2 In areas where the water table will rise above the hydrant drain ports, the drain ports should be plugged and the barrels kept dry to prevent freezing damage to the barrel and water system contamination. Where hydrant drains are not plugged, they shall drain to the ground surface, if topography permits, or to dry wells/drainage pits provided exclusively for that purpose. Under no circumstances should such drains be connected to storm or sanitary sewers.

Par 3 All fire hydrants should be provided with adequate blocking to prevent movement caused by thrust forces.

Par 4 For other hydrant design requirements refer to Section 3.3 and consult with the municipal fire department.

Par 5 For non-design requirements respecting fire hydrants (i.e., colour coding, maintenance, etc.) reference should be made to Ontario Regulation 730/81 - Fire Code.

5.2 VALVES AND VALVE CHAMBERS

Par 1 For the guidelines covering the placement of valves refer to Section 3.2. Also the Municipal Works Department should be consulted regarding their preferences with respect to valve locations at intersections; line valve spacing; types of valves permitted; direction of rotation to open; maximum size of valve permitted in valve box; etc.

Par 2 Wherever possible, valves to be used in water distribution systems should be manufactured in accordance with recognized standards, such as those prepared by AWWA. The following AWWA standards cover valves used in water distribution systems:

- GATE VALVES - 75 mm through 1200 mm - AWWA C500
- RUBBER-SEATED BUTTERFLY VALVES - AWWA C504
- BALL VALVES - SHAFT OR TRUNNION-MOUNTED - 150 mm through 1200 mm FOR WATER PRESSURES UP TO 2100 kPa - AWWA C507
- RESILIENT-SEATED GATE VALVES - AWWA C509

Par 3 Valves 300 mm in diameter, or less, may have access provided to the operating nut via a valve box and stem assembly, but it is the recommendation of the Ministry of the Environment that all valves larger than 300 mm in diameter be placed in valve chambers. Similarly, all air release valves and drain valves should also be located in chambers. To minimize the number of chambers required, consideration should be given to locating combinations of such appurtenances in a single chamber. See Appendix F, Section 7 of the "Guidelines to Govern the Separation of Sewers and Watermains", for the accepted methods for providing drainage for such chambers and watermain appurtenances.

5.3 WATER SERVICES

Par 1 Water services must be at least NPS-3/4 and constructed of materials acceptable under the provisions of the "Plumbing Code" (Ontario Building Code). Municipal Works Departments should be consulted regarding local preferences.

Par 2 In selecting the diameter of a service connection, the designer should consider such factors as the following:

a) Peak water consumption of building serviced;
b) Total length of service which will be required to reach building;
c) Elevation of building;
d) Available head in watermain;
e) Loss of head resulting from considerations a), b), c), fittings and meter;
f) Required head at point of water usage.

Par 3 Recent studies have shown that for residential water services, the peak water demands can be as high as 1.1 L/s. Past practice has been to design for peak flow rates of 0.4 to 0.5 L/s. Head losses become excessive with 20 mm services from water flows much higher than 0.4 L/s. The use of NPS-1 residential water services and larger than minimum meter size should, therefore, be considered, especially in the case of large homes, large lot sizes, deep set backs etc.

Par 4 All water services should be equipped with a corporation stop and a curb stop. The curb stop should be provided with a curb box.

5.4 THRUST BLOCKS

Par 1 Adequate restraint must be provided in water distribution systems to prevent pipe movement and subsequent joint failure. In the case of non-restraining mechanical and/or slip-on joints, this restraint should be provided by adequately sized thrust blocks positioned at all plugs, caps, tees, reducers, wyes, hydrants and bends deflecting 22-1/2°, or more. Depending upon internal pressures, pipe sizes, pipe material, and soil conditions, bends of lesser deflection may also require thrust blocking. An alternative approach that can be used to prevent joint failure is to either use pipe and jointing methods capable of resisting the forces involved (such as welded steel pipe, or polyethylene pipe with thermal butt-fusion joints) or use joint restraining methods, such as suitable metal tie rods, clamps or harnesses.

Par 2 In designing thrust blocks and other restraint systems, the designer should remember that transient pressures should be added to the normal operating pressures when calculating the thrust forces (if velocity of flow is very high, dynamic thrust should also be calculated); adequate corrosion protection must be provided for external clamps and tie rods; the safe bearing values of soils should be reduced substantially from textbook figures if shallow trenches are used. For further discussion of thrust blocking and joint restraint design, reference should be made to the pipe manufacturer's catalogue, and other sources such as textbooks, watermain design manuals, etc.

6.0 BOOSTER PUMPING STATIONS

6.1 GENERAL

Par 1 Water distribution systems may have incorporated within them water booster pumping stations. The purpose of these stations is to maintain adequate pressures and flows in water distribution systems as a result of both changes in ground elevation and distance from the source of supply. Booster pumping stations must be designed to service specific areas of a water distribution system based on defined limits. These areas are generally isolated from the remainder of the system.

Par 2 Pumping stations may have incorporated with part of their operation, elevated or ground storage reservoirs which will, in effect, serve to supply extreme production requirements, such as peak hour, fire flow requirements, etc. This section will address booster pumping stations of the two most common types; without associated storage for the service area and with associated floating storage for the service area in question.

6.2 DESIGN REQUIREMENTS

Par 1 Booster pumping stations, either alone or in conjunction with storage, must be capable of meeting the various demand requirements of the area being serviced. Analysis must be undertaken to determine each of the following conditions:

- maximum hour a.m. flows when industrial and commercial consumption are at their highest;
- maximum hour p.m. flows when residential consumption, including lawn watering is at its highest;
- night flows when the consumption rate is at its lowest value and reservoirs remote from the source of supply are being filled by the booster station;
- fire flows which can occur at any time and which must be added to the maximum day rate.

Par 2 In general, discharge pressure from the pumping station must be adequate to ensure that the pressure in the district to be served is within the range of 275 kPa and 700 kPa, during peak and minimum domestic demand periods. In the case of fire flows, it is assumed acceptable to allow the pressure to drop to a level no lower than 140 kPa.

6.2.1 Pumping Station Design Requirements with No Floating Storage Available

Par 1 If no floating storage is available, the proposed booster pumping station must be designed in a manner that will allow it to supply all of the extreme flow conditions mentioned above.

Par 2 For smaller pressure zones with booster pumping stations, either floating or ground storage may not be available for the particular area to be served. In this instance it is normal that the fire flow requirement is the most onerous. For larger pressure districts served by booster pumping stations, it may become restrictive (i.e., cost prohibitive) both in terms of pumping station capacity and watermain design to attempt to supply all of the extreme flow conditions directly from the booster pumping station. In such instances, floating storage facilities will become necessary for the area in question.

6.2.2 Pumping Station Design Requirements With Floating Storage Available

Par 1 Assuming floating storage is available for balancing, fire and emergency conditions, a booster pumping station must be capable of supplying a firm capacity equal to the maximum day rate.

6.3 PUMPAGE CAPACITY

6.3.1 Firm Capacity

Par 1 Firm capacities shall be defined as follows:

a) Capacity of a pumping station with the largest unit out of service if the station supplies a pressure zone with floating storage available for fire protection and balancing;

b) Capacity of a station with the two largest units out of service if the pumping station serves a zone that does not have floating storage available.

6.3.2 Station Capacity

Par 1 Booster pumping station structures, major piping, etc. should be designed for at least the 20-year estimated flow or if practicable, for the ultimate service area requirements. Alternatively, the initial design should be such as to permit expansion to the ultimate. The initial installation of mechanical and electrical equipment should at least be able to pump the expected 10-year design requirement. The original design should allow for additional pumping units, standby facilities, transformers, and other mechanical and electrical equipment as will be required in future.

6.4 STATION TYPES

Par 1 In general there are two basic types of booster pumping stations that are commonly utilized. The two types of stations to be considered in this document are those making use of horizontal centrifugal pumping units and those making use of vertical turbine units.

Par 2 Typically, horizontal centrifugal units are equipped with side suction and side discharge, with the exception of larger units which may have bottom suction. Horizontal centrifugal units can be used either with an associated reservoir or as a direct inline booster pumping station. Care must be taken to ensure that suitable net positive suction head (NPSH) is available.

Par 3 Typically, vertical turbine pumping units are designed in association with a reservoir or clearwell facility where the units can be placed directly over a reservoir or sump of some kind.

6.5 SITE CONSIDERATIONS

Par 1 To allow for servicing, vehicle access to the pumping station must be provided.

Par 2 If diesel engines are to be utilized for standby power, the requirements of Section 8 of the Environmental Protection Act must be satisfied. A separate application for air approval is necessary. If the isolation from the engine exhaust to the nearest point of impingement is not sufficient to dissipate the air contaminants to within the regulated levels, an exhaust stack may be required.

Par 3 Any electrical controls, switch gear, or transformers located outside must be properly housed and fenced in accordance with the local hydro requirements.

6.6 STANDBY POWER

Par 1 The need for standby power at a booster pumping station should be assessed on an individual basis for the particular system involved. Typically, considerations must be:

a) Availability of floating storage;

b) Availability of a secondary facility for pumping, i.e., locations where more than one booster pumping station supply a single area;

c) The availability of alternate hydro supplies for the booster pumping station;

d) The power outage record for the particular area;

e) Available pressure flow during power outage.

In general, the following approach should be adopted.

Par 2 In cases where no floating storage is available for fire protection, it is generally recommended that full standby power be supplied. Typically, the size of the booster pumping stations in these instances is small and the standby power requirements low. As a result, it is normally the most economical approach to utilize standby diesel generator sets.

Par 3 Where floating storage is available, the need to utilize standby power is less critical. A common approach is to provide sufficient standby power for the pump capacity equal to the average day demand rate. This will supply, in all probability, the necessary quantities of water required in the event of a major power outage in a particular area.

Par 4 If standby power is required, it should be provided by means of either an emergency standby generator set or a direct drive engine.

Par 5 If the generator and motor are not sized to simultaneously run all equipment in the pumping station, the equipment which cannot be run by the unit should be locked out for overload protection.

6.7 PUMPS

6.7.1 System Head Curves

Par 1 For a booster pumping station, a single system head curve cannot be developed due to the changing demands within the system. Projected points of operating head and flow for at least the following conditions under different development scenarios should be developed:

a) average day
b) maximum day
c) maximum hour p.m.
d) maximum hour a.m.
e) minimum hour

Par 2 Care must be taken to ensure that pumps are selected in order that they will operate satisfactorily over the necessary pumping ranges that can be expected at the booster pumping station. In general, the pumps should be capable of meeting at least the following criteria:

a) The rated point which would generally correspond to the maximum day consumption rate;
b) The rated point for efficiency evaluation, i.e. the point at which the pump would normally run and at which the pump should be selected for best efficiency;
c) The possible operating range which would be the range over which the pump must operate from a minimum total dynamic head to a maximum total dynamic head;

d) The minimum submergence level in the case of a vertical turbine unit, or the available NPSH in the case of horizontal centrifugal unit, must also be specified.

Par 2 All four of these criteria must be evaluated when a pump is being selected. Typically, the unit will operate at a total dynamic head considerably less than the ultimate rated point. As a result, the maximum efficiency point should be so specified as to be that point at which the pump will normally run. The rated point must be selected as the point for which the pump will have to overcome the greatest amount of head with a specified flow rate.

6.7.2 Constant Speed vs Variable Speed Pumping Units

Par 1 In certain instances, such as locations where pumps operate on a closed system without the benefit of floating storage, it may be advantageous for flow pacing to be considered. If variations in pressure are critical to the system, it may be necessary to supply variable speed pumps.

6.8 WET WELLS

Par 1 In instances where wet wells/reservoirs are utilized, the wet wells/pump suction chamber should be isolated from adjacent reservoirs in order to gain access as required.

Par 2 Wet wells/reservoirs should be divided with suitable valving in order that an alternate section of the wet well can be utilized to permit maintenance or modification in another section without disrupting the operation.

Par 3 Wet well sizes and submergence levels on pumping units should be such that they conform to the "Hydraulic Institute Standards for Centrifugal, Rotary and Reciprocating Pumps".

6.9 SUCTION AND DISCHARGE PIPING

Par 1 Suction and discharge piping should be designed and arranged in such a way that it is easily accessible. The following general points should be considered in the design of the various components of the sytem:

a) Suction piping must be designed in such a way to ensure that the NPSH requirements for the pumping unit involved are satisfied (positive suction design is recommended over negative suction);
b) Suction velocities should normally be maintained at no greater than 2.5 m/s;
c) An isolating gate valve, should be installed on the suction side of the pump;
d) Velocities for discharge piping may range as high as 5.0 m/s;
e) Care should be taken in the design of piping, such that all joints are restrained in a manner that will not permit joints to pull apart;

f) In an in-line booster pumping station, the pressure on the suction side of the pump should not be allowed to drop below 140 kPa when there are service connections on the suction side watermain.

6.10 VALVES

Par 1 Valves, either of the gate or butterfly type, may be used for pump isolation and/or pump discharge operation. Typically, on larger installations (i.e., 250 mm or greater), butterfly valves should be utilized. Gate valves, especially for suction isolation, may be utilized for smaller sized piping.

6.11 CHECK VALVES

Par 1 Some form of self-closing check valve must be incorporated in the discharge of each unit in the pumping station. Valves may act hydraulically or mechanically, but should all be designed in such a way that if station or pump flow is lost, the valve will close automatically.

Par 2 The type and arrangement of check valves and discharge valves are dependent, in some part, on the potential hydraulic transients that might be experienced in the pumping station. Typically, in smaller pumping stations, mechanically operated check valves are adequate. However, in large stations, considerable care must be taken with respect to the method of starting and stopping the pumps. Typically, an electrically operated butterfly valve, coupled with a check valve, on the discharge may be utilized for the starting and stopping sequence of a pump. Other types of valves may incorporate both the isolating valve and check valve characteristics into one common valve. Care, however, should be taken to ensure that suitable isolating valves are available in the event that maintenance is required on combination type valves.

6.12 FLOW METERS

Par 1 It is a generally accepted practice that a flow meter be installed in the pumping station to measure the pumping rate. Typically, a magnetic flow meter, an insert venturi meter or a mechanical meter may be utilized for this purpose.

6.13 PIPE MATERIAL

Par 1 Although there are several types of material which can satisfactorily function for use in a booster pumping station, it has generally been found in recent years, that stainless steel or concrete pressure pipe have advantages over other types of piping. Although it is not recommended that only stainless steel or concrete pressure pipe be specified, one should consider it as an economic material, both in terms of its ease of installation and the minimum maintenance required.

6.14 SURGE ARRESTOR SYSTEMS

Par 1 A hydraulic transient analysis should be undertaken for each booster pumping station to be designed, to ensure that the transients resulting from pumps starting, stopping, full load rejection during power failure, etc. do not adversely affect either the customers on the water system, or the piping in the station or the system. Typically, methods of surge protection that can be used to protect booster stations include:

a) Surge anticipator systems that dissipate over-pressure from the discharge lines;
b) Slow closing and opening control valves on pump discharges;
c) Hydropneumatic surge tanks on discharge headers;
d) Variable speed pumping units.

6.15 MOTORS

Par 1 Each pump, typically, is operated by an electric motor capable of operating the pump over the full range of load conditions. Care must be taken to ensure that the motors are energy efficient. It is generally accepted that motors should be located at such a level in the pumping station that they cannot easily be flooded should a pipe failure occur.

6.16 TRANSFORMERS

Par 1 Suitable transformers should be supplied to meet all requirements in the pumping station. For larger pumping stations, it is generally an accepted practice that dual transformers and switch gear be supplied, in order that continuous operation of at least half of the pumping station can be maintained.

6.17 GENERAL DESIGN CONSIDERATIONS

Par 1 Lifting devices of some type should be incorporated into the design of the structure so that pumps and/or motors can easily be transferred from and to their location within the station.

Par 2 Although it is not normally necessary to supply dehumidification in a booster pumping station, sufficient ventilation must be supplied to ensure that the heat generated from the electrical equipment is sufficiently dissipated.

Par 3 If the distance from one exit is greater than 4.5 m, two exits must be supplied for the pumping station.

Par 4 A sump pump should be supplied to ensure that any miscellaneous water entering the station is removed.

6.18 SAFETY PRECAUTIONS

Par 1 Stations should be designed in such a manner as to ensure the safety of the operators in accordance with the Occupational Health and Safety Act. Typically, the following points should be considered.

a) Any rotating equipment should be covered with suitable guards to prevent accidental contact;

b) Equipment that starts automatically should be suitably signed to ensure that operators are aware of this situation;

c) Lockouts on all equipment should be supplied so that maintenance personnel can ensure that they are completely out of service;

d) All stairways, walkways, etc. should be properly designed with guardrails.

Par 2 More specifics respecting safety should be obtained from the Ministry of Labour.

6.19 STATION MONITORING

Par 1 Typically, station functions should be monitored to ensure that the station is performing satisfactorily. Monitoring signals and alarms are normally transmitted to a central location which is manned on a 24-hour basis. In the case of very small stations, a single alarm, covering a variety of points, may be acceptable. In larger stations, typically the following signals and alarms should be considered for transmission to a central monitoring point:

Signals

a) station flow,
b) station pressure,

Alarm Points

a) pump alarms, including:
    i) discharge pressure too low,
    ii) discharge pressure too high,
    iii) motor temperature alarm.

b) station alarm points, including:

- i) building temperature alarm,
- ii) building fire alarm,
- iii) building station flood,
- iv) power failure alarm,
- v) illegal entry alarm,
- vi) surge valve alarm.

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MINISTRY OF THE ENVIRONMENT

GUIDELINES FOR THE DESIGN OF WATER STORAGE FACILITIES

JULY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

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In 1982 a committee was established to undertake a general revision of the guideline document. The members of this committee were as follows:

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1.0 INTRODUCTION

Par 1 It is the intention of the Ministry that these guidelines be utilized in determining the size of water storage facilities to be provided in water supply systems, requiring approval under the Ontario Water Resources Act.

Par 2 For further recommendations regarding storage associated with water supply systems servicing 500 or fewer persons, referencee should be made to the MOE publications entitled " Guidelines for the Design of Water Supply Systems for Small Residential Developments" and "Guidelines for the Design of Seasonally Operated Water Supply Systems"

Par 3 The method of determining total storage requirements detailed in these guidelines is, in the opinion of the Ministry, a reasonable one. However, it should not be construed as fulfilling the requirements (fire) of the municipality's insurance company or the Fire Underwriters Survey - Insurers Advisory Organization. Since fire protection is a municipal responsibility, it is quite feasible that a municipality may elect to provide for higher fire flow requirements or entirely forgo fire protection via the potable water distribution system.

Par 4 It is recommended that water supply, distribution and storage systems not be sized to meet the requirements of higher demand or higher risk (fire) industries (or other establishments) unless prior arrangements have been made with the industry for cost sharing. See Appendix N for the recommended sizing of water storage facilities.

Par 5 As previously mentioned, the level of fire protection provided is the responsibility of the municipality in the case of the design of a municipal system and the responsibility of the individual owner in the case of the design of a private system. In either case, however, the requirements of the Ontario "Fire Code" (Ontario Regulation 730/81) should be addressed. Designers should, therefore, familiarize themselves with the requirements of this Regulation.

Par 6 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left hand margin of each page.

Par 7 As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with in order to obtain approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health concerns can be safeguarded by alternative approaches, such methods will be considered for approval.

2.0 TYPES OF WATER STORAGE FACILITIES

Par 1 In a water supply system there are alternative methods available for the provision of water storage. Storage can be provided at the water purification plant and/or in the water distribution system as follows:

Water Purification Plant	- clearwell storage - ground level storage
Distribution System	- elevated storage - ground level storage

Par 2 The type of water storage facility selected will depend on many factors such as size of service area, topography, costs, etc. It is not the intention of the guidelines to assist the designer with the selection of the most appropriate or economical type of storage. These guidelines should be used to establish the total water supply system storage requirements and used in the detailed design of the selected water storage facility.

Par 3 The top water level and the location for a storage facility floating on the distribution system should be selected to result in acceptable service pressures throughout the distribution system as outlined in the "Guidelines for the Design of Water Distribution Systems".

3.0 SIZING OF STORAGE FACILITIES

Par 1 The total water storage requirements (exclusive of storage required for the operation of the water purification plant) for a given water supply system should be established based on the method outlined in Appendix N. As noted above, the storage can be located at the water plant site and/or within the distribution system and can be elevated and/or ground level, depending on many factors.

Par 2 The design method outlined in Appendix N assumes that the water treatment plant is capable of satisfying only the maximum day demand. If it capable of supplying more than this, the storage requirements can be reduced accordingly.

3.1 STORAGE REQUIRED FOR THE OPERATION OF THE WATER PURIFICATION PLANT

Par 1 Some storage is required at the water purification plant site for the proper operation of the plant. This storage is in addition to the storage requirement based on the design criteria in Appendix N.

Par 2 This storage at the plant site should be calculated based on the volume of the filter backwash water required and there should be some allowance for the volume of water required when a filter is out of service during backwashing.

Par 3 The site storage can be provided in a clearwell or in a separate ground storage reservoir. Refer to the Ministry of the Environment's

"Guidelines for the Design of Water Treatment Works" for more information on plant site storage.

4.0 DESIGN GUIDELINES FOR STORAGE FACILITIES

4.1 GROUND STORAGE RESERVOIRS

4.1.1 Site Selection

Par 1 After the top water level of the reservoir has been set then a site should be selected which results in an economical design. Most ground level reservoirs have a water depth of approximately 6 m. An economical design usually results if the excavation below original ground is about one-half of the total water depth.

Par 2 When locating the reservoir relative to the existing ground, many factors should be considered such as:

- structural costs based on soils conditions and location of the ground water table;
- excavation costs based on cut and fill considerations;
- the top of the reservoir should not be less than 0.6 m above the original ground surface or maximum flood level of any adjacent body of water.

Par 3 Other factors which should be considered when locating a ground storage reservoir are:

- sewers, drains, septic tanks and tile fields, standing water and similar sources of contamination must be kept at least 15 m away from the reservoir (water pipe, pressure tested to MOE Standard Specification for the Construction of Sewers and Watermains in accordance with MOE 02660, Section 3.21 at a pressure of 350 kPa, with no leakage, may be used for gravity sewers where lesser separations are unavoidable);

- future expansion;
- site access.

4.1.2 Number of Cells

It is prefereable that all ground storage reservoirs be constructed with two or more cells and a separate pumpwell when applicable, in order to facilitate routine maintenance (cleaning) etc. Through valving it should be possible to isolate one of the two cells for inspection or maintenance operations without affecting the operation of the other cell. Quite often two cells can readily be provided as a result of phasing requirements.

4.1.3 Protection

Par 1 Locks on access manholes and valve and vent houses should be provided, along with taking other precautions to guard against trespassing, vandalism and sabotage.

Par 2 Further, when the reservoir is located on farmland, the site should be fenced to prevent farm animals from having access to the reservoir roof.

Par 3 All finished water storage structures should have suitable watertight roofs and any opening should have suitable covers to prevent entrance of birds, animals, insects or excessive dust.

4.1.4 Roof and Sidewall

Par 1 The roof and sidewalls of all structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a) Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks, or should be connected to standard wall castings which were poured in place during the forming of the concrete structure. These wall castings should have flanges imbedded in the concrete.

b) Openings in a storage structure roof or top, designed to accomodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water into the reservoir proper.

c) Where possible, valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir. As an alterative approach, such valves and controls may pass through the roof or reservoir top provided they are located within a valve or pumphouse structure on the roof and are curbed.

4.1.5 Drainage for Roof or Cover

Par 1 The roof or cover of the storage structure should be well drained, but down-spout pipes shall not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water on the roof, will not be approved.

4.1.6 Access

Par 1 Finished water storage structures shall be designed with convenient and safe access (i.e., minimum 900 mm x 1060 mm opening) to the interior for cleaning and maintenance. The number and location of access hatches should comply with the Occupational Health and Safety Act.

Par 2 Manholes above waterline:

a) Manholes should be elevated 450 mm above the top or covering sod;
b) Should be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 100 mm;
c) Should be hinged at one side using non-removable hinges;
d) Should have a locking device. An acceptable securing method is to use two (2) 25 mm minimum diameter steel rods passing through the cover, flange and frame and equipped with padlocks.

4.1.7 Vents

Par 1 Finished water storage structures shall be vented by special vent structures. Open construction between an outside wall and the roof is not permissible.

These vents shall:

a) Prevent the entrance of surface water;
b) Exclude birds and animals;
c) Exclude insects and dust, as much as this function can be made compatible with effective venting;
d) On ground level structures, terminate in an inverted 'U' construction, the opening of which is 600 to 900 mm above the roof or sod and is covered with twenty-four mesh non-corrodible screen cloth. Vents should be located away from areas which will be subject to severe snow drifting. Where a valve or pump house is provided, the vents should be located within the structure.

4.1.8 Drains

Par 1 It is recommended that no drain on a water storage structure be directly connected to a sewerage works facility. (i.e., sanitary sewer, storm sewer, sewage pumping station etc . Should such a connection be unavoidable, an atmospheric gap of twice the drain diameter must be provided.

4.1.9 Overflow

Par 1 It is recommended that no overflow be directly connected to a sewerage works facility except where an atmospheric gap equivalent to twice the overflow diameter can be provided.

Par 2 The overflow of a ground level structure shall be high enough above original or finished grade to prevent the entrance of surface water.

4.1.10 Circulation

Par 1 Positive circulation of the water in the reservoir should be provided wherever possible, to avoid depletion of the chlorine residual and reduce the potential for stagnation. This is generally accomplished by the provision of two cells and by strategic location of the inlet and outlet piping. Where there is more than one cell then the inlet should be to one cell and the outlet from another. This will ensure that there is good circulation from one cell to another. There should, of course, be the flexibility for operating with one cell out of service.

4.1.11 Freezing

Par 1 All finished water storage structure and their appurtenances, especially overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning.

4.1.12 Internal Catwalk

Par 1 Every catwalk over finished water in a storage structure shall have a solid floor with 100 mm edges so designed that shoe scrapings and dirt will not fall into the water.

4.1.13 Grading

Par 1 The area surrounding a ground-level structure should be graded in a manner such that water is directed away from the structure. Side slopes should have a grade no steeper than 3:1 for grass cutting purposes.

4.1.14 Painting and/or Cathodic Protection

Par 1 Proper protection should be given to metal surfaces by paints, varnishes and cathodic protection systems, etc.

4.2 SPECIAL CONSIDERATIONS FOR CLEARWELL STORAGE AT WATER PLANTS

4.2.1 Adjacent Compartments and Pipes Through Clearwells

Par 1 Potable water should not be stored or conveyed in a compartment adjacent to non-potable water when the two compartments are separated by a single wall.

Par 2 Pipes carrying non-potable water should not be installed through potable water retaining structures.

Par 3 Deviations from these requirements will only be permitted on a case-by-case basis, if the designer is able to show that compliance with the requirement is significantly uneconomical or physically impractical and that alternate design features provide acceptable and/or equivalent levels of protection against contamination.

4.2.2 Basins and Wet-wells

Par 1 Receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

Par 2 When finished water storage is used to provide proper contact time for chlorine, special attention must be given to size and baffling.

4.3 ELEVATED STORAGE FACILITIES

4.3.1 Pressure Variation

Par 1 The maximum variation between high and low levels in storage structures which float on a distribution system should be such that the pressures in the distribution system do not go above 700 kPa nor below 275 kPa under normal demand periods. Pressures as low as 140 kPa may be acceptable when fire demands are experienced in conjunction with maximum day consumption rates.

Par 2 The geometry or physical configuration of the water containing portion of the tank should be such that the equalization volume (B) is located between the TWL of the tank and that elevation necessary to produce a minimum pressure of 275 kPa in the majority of the system under peak hourly flow. The fire (A) and emergency (C) component volumes (i.e., A + C) should be located between that elevation necessary to produce 275 kPa under peak hourly flow conditions and that elevation necessary to produce a minimum 140 kPa under the maximum day plus fire flow condition.

Par 3 Should a standpipe with a booster pumping station at the base be proposed, the equalization volume (B) would normally located between the TWL and that elevation necessary to produce 275 kPa in the majority of the system under peak hourly flow. The fire (A) and emergency (C) components should/can be below this 275 kPa elevation provided the booster pump is designed/sized to increase system pressures to a minimum 140 kPa under the maximum day plus fire flow condition.

4.3.2 Protection

Par 1 Fencing of the storage site and locks on access manholes should be provided, along with taking other precautions to guard against trespassing, vandalism and sabatoge.

4.3.3 Access

Par 1 Finished water storage structures shall be designed with reasonably convenient access (i.e., minimum 1000 mm ¢ opening) to the interior for cleaning and maintenance.

4.3.4 Vents

Par 1 Finished water storage structures shall be vented by special vent structures. These vents should:

a) Prevent the entrance of precipitation;
b) Exclude birds and animals;
c) Exclude insects and dust, as much as this function can be made compatible with effective venting; four-mesh non-corrodible screen may be used.

4.3.5 Drainage

Par 1 Systems which incorporate storage structures which float on the distribution system should have the structures so designed that the distribution system pressures may be maintained when the reservoir is drained for cleaning or maintenance. The drains should discharge to the ground surface and it is recommended that no direct connection to a sewerage works facility should be made unless there is an atmospheric gap equivalent to twice the diameter of the drain.

4.3.6 Overflows

Par 1 Overflow pipes should be designed to discharge the maximum pumping rate to the reservoir.

Par 2 The overflow pipe of an elevated storage tank should be brought down near the ground surface and discharged near a drainage outlet structure or a splash pad. No overflow should be connected directly to a sewerage works facility without an atmospheric gap equivalent to twice the diameter of the overflow.

4.3.7 Freezing

Par 1 Elevated tank structures and standpipes and their appurtenances should be designed to reduce the occurrence of problems due to freezing. Alternatives to be considered in this regard include insulation; internal heating via heat tracing cables; hot water recirculation; separate inlet (high) and outlet (low) piping or a combination of these methods. Reference should be made to the MOE publication "Guidelines for Servicing in Adverse Conditions" for further information on reducing freezing problems in elevated storage.

4.3.8 Controls

Par 1 Adequate controls along with overflow and low level warning alarms shall be provided to maintain acceptable levels in distribution system storage structures.

a) Telemetering equipment should be used when pressure type controls are employed and any appreciable head loss occurs in the distribution system between the source and the storage structure.

b) Altitude valves should be installed on elevated storage when more than one tank is required within a single supply pressure zone.

c) Overflow and low-level warnings or alarms activated by separate and independent pressure switches should be annunciated at places in the community where there will be responsible surveillance, preferably on a 24-hour basis.

d) In general, it is the preference of operators that the high lift pumps in a system be run on an on-off cycle with the signal being actuated by a predetermined and adjustable drop in the storage tank, (i.e., elevated tank or standpipe).

Par 2 This mode of operation is felt to be the simplest and will reduce the possibility of stagnant water or freezing in the storage tank.

4.3.9 Design Requirements for Steel Water Storage Tanks

The design of steel water storage tanks should be in accordance with the applicable ANSI/AWWA (AWS) specification (i.e., ANSI/AWWA D100 (AWS D5.2)).

4.3.10 Protective Coating of Steel Water Storage Tanks

Par 1 During 1983, the Ministry of the Environment commissioned a report entitled "Survey and Evaluation of Protective Coating Systems for Steel Water Storage Tanks". As a result of that report, MOE Standard Specification No. 10 "Steel Water Storage Tanks - Exterior and Interior Protective Coatings" was prepared.

Par 2 Copies of this Standard Specification can be obtained from;

Environmental Approvals and
Project Engineering Branch,
135 St. Clair Avenue West,
Toronto, Ontario. M4V 1P5

5.0 SAFETY

5.1 PERSONNEL SAFETY

Par 1 The safety of the employees must be considered in the design of the storage structure. As a minimum, such matters shall conform to the Ministry of Labour requirements and other pertinent laws and regulations of the Province.

a) Ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.
b) Elevated tanks with riser pipes over 200 mm in diameter shall have protective bars over the riser openings inside the tank.

5.2 EQUIPMENT CONTAINING MERCURY

1. Equipment containing mercury may not be connected permanently to any liquid system within a water treatment plant or water storage facility where it is possible that mercury may escape into water which susequently is delivered to consumers.

2. Calibration and test equipment containing mercury for which no alternatives exist may be used provided no permanent connection to a potable water system exists.

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2. "Water Supply for Public Fire Protection - A Guide to Recommended Practice", (1981), Fire Underwriters Survey, Insurers' Advisory Organization, 180 Dundas Street West, Toronto, Ontario, M5G 1Z9, 416-597-1200

3. "Guidelines for the Design of Water Supply Systems for Small Residential Developments", Ministry of the Environment, Environmental Approvals and Project Engineering Branch, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5.

4. "Guidelines for the Design of Seasonally Operated Water Supply Systems", Ministry of the Environment, Enviromental Approvals and Project Engineering Branch, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5.

5. "Guidelines for Servicing in Areas Subject to Adverse Conditions", Ministry of the Environment, Environmental Approvals and Project Engineering Branch, 135 St. Clair Avenue West, Toronto, Ontario, M4V 1P5.

6. "Fire Code", Ontario Regulation 730/81 made under the Fire Marshals Act, November 1981, Government of Ontario, Queen's Park, Toronto, Ontario.

7. "Guidelines for the Design of Water Treatment Works", Environmental Approvals and Project Engineering Branch, 135 St. Clair Avenue West, Toronto, Ontario, M4V 1P5.

GUIDELINES FOR SERVICING IN AREAS SUBJECT TO ADVERSE CONDITIONS

JANUARY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

The Honourable
Jim Bradley
Minister

Allen E. Dyer, Ph.D., M.D.
Deputy Minister

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1.0 INTRODUCTION

.01 Due to the ever increasing development in areas of the Province where adverse servicing conditions exist, there is a need to present, in the form of a guideline, the alternate technologies and materials that are available at present (and which must be expanded upon) to better service development in such areas.

.02 For the purposes of these guidelines, 'servicing' is defined as 'communal sewer and water servicing' alone.

.03 The adverse conditions that exist in an area may be a result of: the climate, the geology, the hydrogeology, the location (remoteness) of the area, a low population density, the topography or any combination of these factors.

.04 The above mentioned adverse conditions are generally associated with communities that have low population densities. Unless alternate technologies are utilized, the per capita costs of servicing these areas may be excessively high. In the past, these high costs have been borne by not only the residents of the community but also by the Government which has heavily subsidized these servicing projects.

.05 This document presents some design guideline suggestions and ideas which hopefully will assist in the application and design of the alternate technologies presently available for the servicing of areas that are affected by adverse conditions.

.06 These guidelines should not be confused with standards or regulations which must be absolutely complied with in order to obtain a Certificate of Approval from the Ministry of the Environment. It is not the intention of the Ministry of the Environment to stifle innovation, nor is it the intention of the Ministry to dictate the standards which must be utilized for the servicing of communities that are affected by adverse conditions.

.07 To allow the guidelines to be more simply modified in future and to permit faster reference by the users to specific paragraphs of the text, the guidelines have been broken down into numbered sections and paragraphs as shown along the left-hand margin of each page.

.08 Throughout the text references (i.e., 1, 4, 7) are made. The references are contained in the "References/Bibliography" contained at the end of this guideline.

2.0 ADVERSE CONDITIONS AFFECTING SERVICING

.01 As previously mentioned, the adverse conditions that exist in an area and that will have an effect upon the servicing design may be as a result of the climate, the geology, the hydrogeology, the location (remoteness) of the area, or any combination of these factors. Since we are only concerned with below ground servicing in these guidelines, only factors which may have an effect upon the ground conditions, and hence service conditions, will be discussed.

2.1 CLIMATIC FACTORS

.01 The main climatic factor having an adverse effect on ground conditions is low temperatures. With below freezing temperatures, one must determine whether the conditions are such that the proposed service will freeze or be otherwise adversely impacted. The main climatic elements that can affect low ground temperatures are cold air temperatures and the amount of snow cover.

.02 The main indicator utilized to determine the relative "air coldness" of an area is the 'Freezing Index'. The 'Freezing Index' is defined as the number of degree days (above and below 0°C) between the highest point in the autumn and the lowest point the next spring on the cumulative degree-day time curve for one freezing season. Figures 2-1, 2-2 and 2-3, are the freezing index maps for Ontario, Canada and Alaska. These maps indicate that the freezing indexes for Alaska, Yukon Territories, Northwest Territories, and Northern Ontario are very similar. The table on page E-4 of Appendix E list the freezing index at various locations in the Province of Ontario. It may also be advisable in some instances to consider the coldest month.

.03 The other climatic element affecting ground temperatures is the amount of snow cover that occurs in the area. In areas with equal air temperatures, the ground temperature will be higher in the areas with the greater snow cover. Figure 2-4 shows "Annual Snow Fall Map of Ontario". This figure has been reproduced from the 'Hydrological Atlas of Canada' by Fisheries and Environment Canada.

.04 In the design of any system, the protection theoretically afforded by snow cover should not be assumed as heavy frost can occur prior to significant accumulations or snow fall could be below normal.

.05 Experience has shown that the climatic factor most seriously impacting the design operation and cost of piped services is frost and the depth to which it penetrates. Frost will only occur in sub-zero temperature and the depth to which it penetrates depends upon the freezing index, the frost susceptibility of the soil and the thermal conductivity of the soil. Methods for determining the frost depth penetration is various soils are presented in Appendix "E".

.06 Another factor to be considered in any design is frost heave. Frost heave is the rise of the ground surface due to frost action. As the water in the pores of the soil freezes, there is an associated increase in the volume of the soil as a whole of up to 5%. If, however, ice lenses form in the soil, much greater increases may occur. Any service system that is to be constructed within the frost zone must be designed with the above and the resultant movement in mind.

2.2 GEOLOGICAL FACTORS

.01 The predominant geological factor which can have an adverse effect on service design conditions is the presence of rock and its proximity to the surface. This phenomenon is common in many areas of the Province and predominant in Northern Ontario where the main geological feature is the Precambrian formation of the Canadian Shield.

.02 Other factors of interest/concern respecting the geology/soils of the northern parts of the Province and hence the design of services are:

- (a) the presence of muskeg which can be found in depths varying from less than 0.3 m to in excess of 3.0 m;
- (b) soil classification and frost susceptibility;
- (c) soil thermal conductivity;
- (d) soil chemistry (i.e., acidic and alkali soils);
- (e) the presence of a high water table.

2.3 LOCATION (REMOTENESS)

.01 In certain northern regions of the province, the mere location of the community to be serviced may be a factor in the design. Access to the site may be difficult, limited and/or expensive due to the lack of adequate road or rail transportation.

.02 These access problems affect the supply of materials, construction equipment, replacement parts, servicing, etc. In these areas, it may be prudent to ensure that the servicing methods are adapted as simply as possible to suit local conditions. If special fittings and accessories are required that may be difficult to obtain, replace, and service, this should be considered at the design stage and spares purchased during construction.

2.4 COMBINATIONS

.01 In most situations, it is combinations of the preceding factors that produce the "ground rules" for the design of any servicing.

2.5 PERMAFROST

.01 Definitions

(a) Permafrost is defined as soil, bedrock, or other material that has remained below 0°C for two or more years.

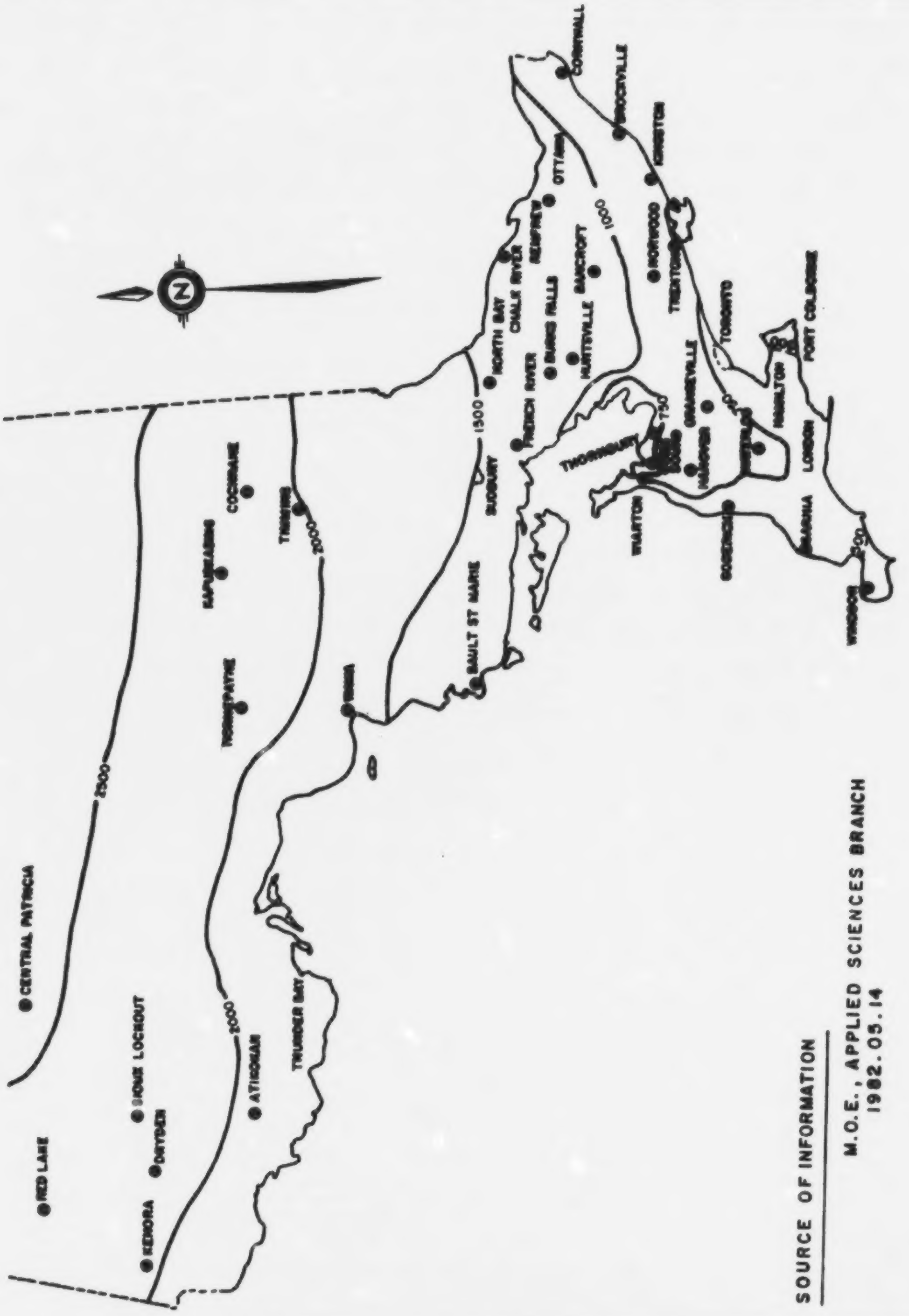
(b) Continuous Permafrost occurs in areas that are underlaid by permafrost with no thawed areas.

(c) Discontinuous Permafrost occurs in an area underlain mostly by permafrost but containing small areas of unfrozen ground.

.02 In Ontario, a state of discontinuous permafrost exists north of the line drawn from the southern tip of Hudson Bay, westerly to the point where the 53°N parallel intercepts Ontario's western boundary, to the 55°N parallel. Reference should be made to the

"Hydrological Atlas of Canada" by Fisheries and Environment Canada for detailed permafrost location information.

.03 Passive construction is usually used in permafrost conditions. This maintains the state of frozen permafrost by constructing insulated services. Over the past ten years, considerable advancement has been made in the design and construction techniques for service systems located in extremely cold and permafrost conditions. The literature outlined in the bibliography should be consulted for more detailed information if required. However, experience to date would suggest that permafrost conditions will not be met in any but the most remote northern areas of the Province.



CORNWALL
BROCKVILLE
KINGSTON
OTTAWA
RENFREW
CHALK RIVER
NORTH BAY
BANCROFT
HUNTSVILLE
BURKS FALLS
FRENCH RIVER
SUDBURY
NORWOOD
TRENTON
TORONTO
PORT COLBORNE
HAMILTON
LONDON
ORANGEVILLE
HANOVER
WIARTON
GODERICH
SARNIA
WINDSOR
SAULT ST MARIE
KAPUSKASING
COCHRANE
TIMMINS
HORNEPAYNE
CENTRAL PATRICIA
RED LAKE
SIOUX LOOKOUT
DRYDEN
KENORA
ATIKOKAN
THUNDER BAY
N
750
1000
1500
2000
2000
2500

SOURCE OF INFORMATION

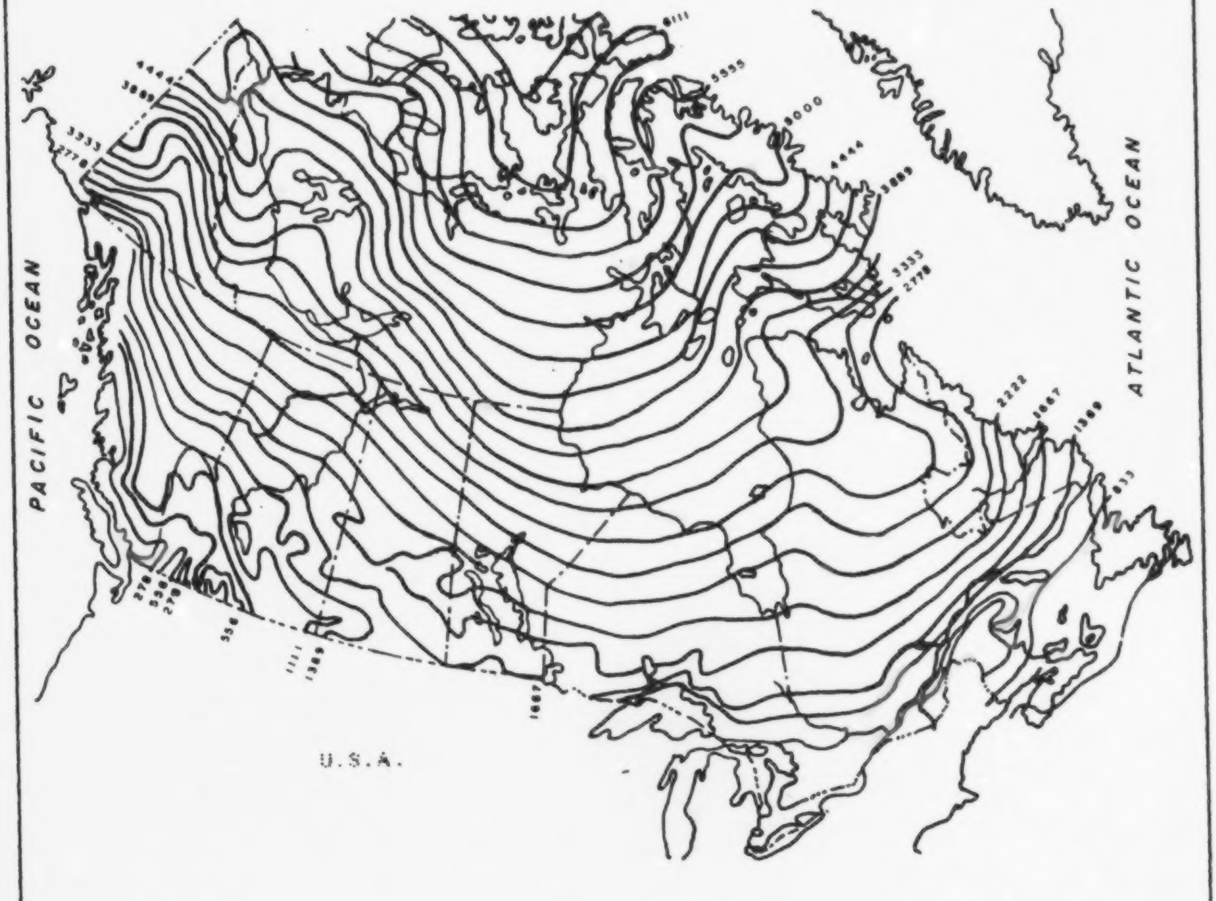
M.O.E., APPLIED SCIENCES BRANCH
1982.05.14

ONTARIO
MINISTRY OF THE ENVIRONMENT

DESIGN FREEZING INDEX
(DAYS-°C)
PROVINCE OF ONTARIO

FIG. 2-1

DATE: APRIL 1984


PACIFIC OCEAN
ATLANTIC OCEAN
U.S.A.
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3333
2778
6111
5555
5000
4444
3889
3333
2778
2222
1667
1389
833
278
556
278
556
1111
1389
1667

SOURCE OF INFORMATION
ENVIRONMENT CANADA

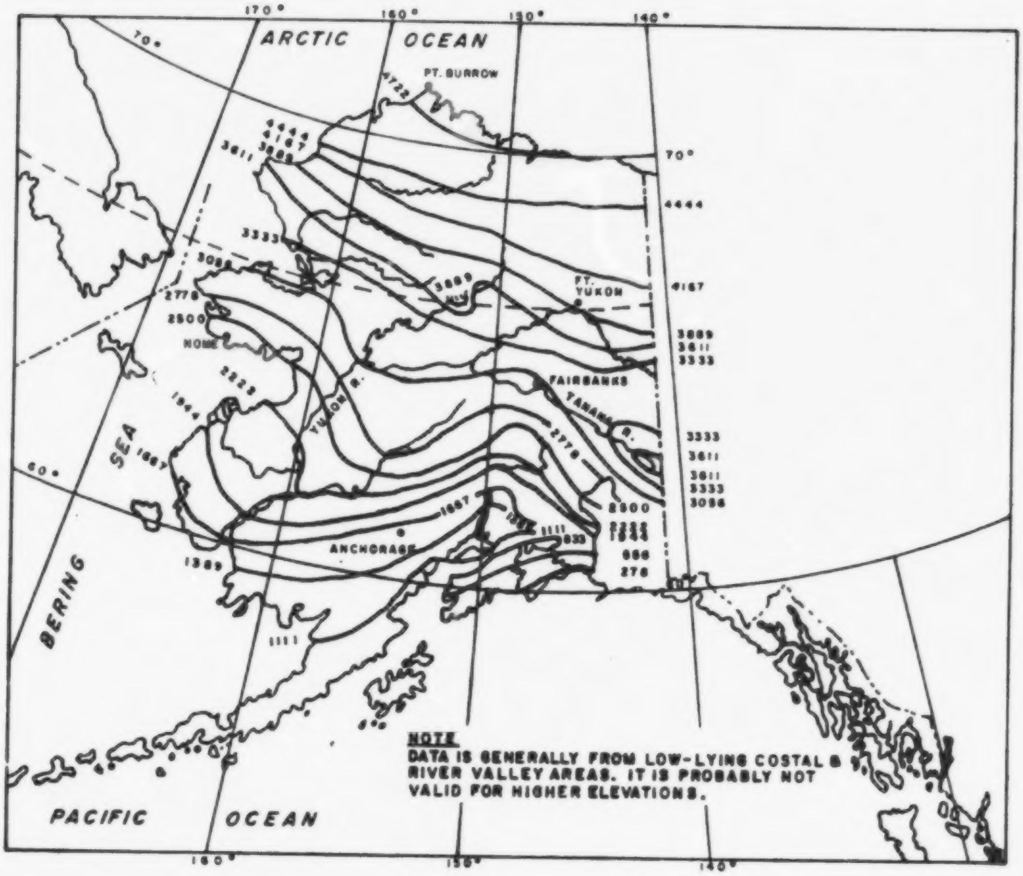
NOTE
MAP HAS BEEN CONVERTED
TO (DAYS- °C)

ONTARIO
MINISTRY OF THE ENVIRONMENT

DESIGN FREEZING INDEX
(DAYS- °C)
ACROSS CANADA

FIG. 2-2

DATE APRIL 1984


170°
160°
150°
140°
ARCTIC OCEAN
70°
PT. BURROW
4722
4444
4167
3889
3611
70°
4444
3333
3056
3889
PT. YUKON
4167
2778
2500
NOME
3889
3611
3333
2222
YUKON R.
FAIRBANKS
TANANA R.
1944
SEA
1667
3333
3611
2778
60°
3611
3333
3056
1667
1389
1111
833
2500
2222
1944
556
278
ANCHORAGE
1389
BERING
1111
PACIFIC OCEAN
160°
150°
140°

NOTE
DATA IS GENERALLY FROM LOW-LYING COSTAL & RIVER VALLEY AREAS. IT IS PROBABLY NOT VALID FOR HIGHER ELEVATIONS.

SOURCE OF INFORMATION

ENVIRONMENTAL ATLAS OF ALASKA; JOHNSON AND HARTMAN; UNIVERSITY OF ALASKA.

NOTE

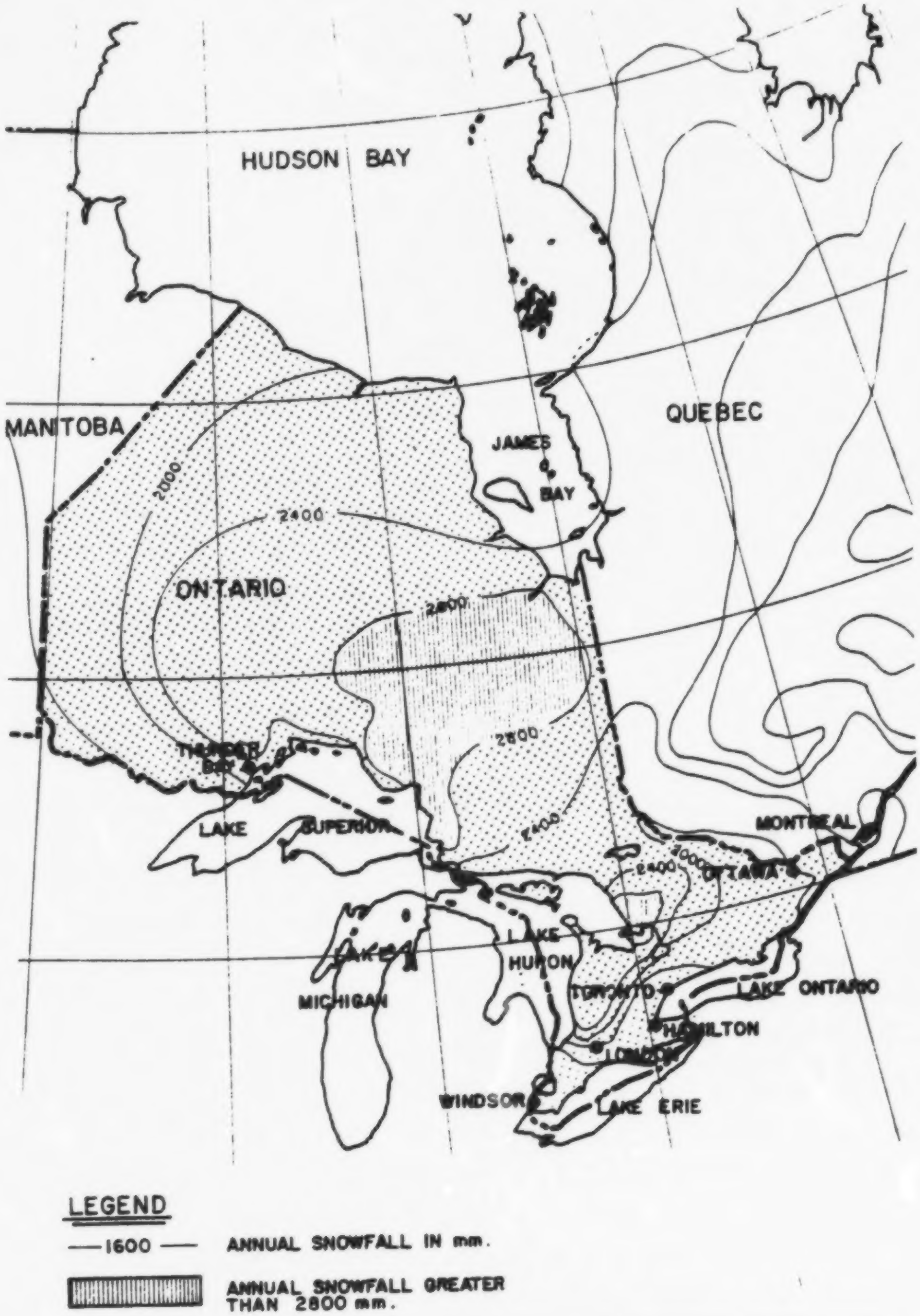
MAP HAS BEEN CONVERTED TO (DAYS- °C)

ONTARIO
MINISTRY OF THE ENVIRONMENT

DESIGN FREEZING INDEX
(DAYS- °C)
ACROSS ALASKA

FIG. 2-3

DATE APRIL 1984


HUDSON BAY
MANITOBA
QUEBEC
JAMES BAY
ONTARIO
2000
2400
2800
2800
2400
2400
2000
THUNDER BAY
LAKE SUPERIOR
MONTREAL
OTTAWA
LAKE HURON
LAKE MICHIGAN
TORONTO
LAKE ONTARIO
HAMILTON
LONDON
WINDSOR
LAKE ERIE
LEGEND
1600
ANNUAL SNOWFALL IN mm.
ANNUAL SNOWFALL GREATER THAN 2800 mm.

ONTARIO
MINISTRY OF THE ENVIRONMENT

ANNUAL SNOWFALL
MAP OF ONTARIO

FIG. 2-4

DATE: APRIL 1984

SOURCE OF INFORMATION:
HYDROLOGICAL ATLAS OF CANADA,
FISHERIES AND ENVIRONMENT CANADA

3.0 CONVENTIONAL DESIGN

3.1 GENERAL

.01 In this section, conventional design practices and some of the design and installation problems associated with these practices will be outlined.

.02 Alternative design practices/technologies are outlined in Section 4.0.

3.1.1 Watermains

.01 In Ontario, the governing factor affecting the design depth of watermain and service connection installations is the necessity to protect the pipe and its contents from the effects of frost.

.02 Accepted practice for years has been to locate the watermain/service connection at such a depth that it is either below the frost line or the incidence of frost-related "failures" is at an acceptable level. As can be seen from the formulae presented in Appendix E, the required burial depth (i.e., frost penetration depth) varies dramatically across the province from approximately 1.2 m to greater than 3.0 m.

.03 In many situations, the frost penetration has exceeded that assumed in design with the result that the pipe and/or its contents have been adversely affected by the frost. This damage inevitably has resulted in increased operations, maintenance and capital costs.

.04 In areas where little or no overburden exists (i.e., rock), it is the practice to blast the required trench and remove the rock. The fragmented rock is often returned to the trench after a "protective" layer of cover material is placed over the pipe. This practice, while resulting in the installation of the service neglects the fact that the large voids present in the rock backfill are conducive to greater frost penetration. In some instances, the rock backfill is replaced with granular backfill which is less conducive to frost penetration. In either case, the high thermal conductivity of the surrounding rock has been neglected/forgotten and it is doubtful if substitution of granular backfill for the blastings has the desired effect thermally.

.05 In areas where a high water table exists, procedures such as the following are usually employed: lower the level of the water table below the invert of the pipe trench by means of portable pumps; a well-point system; interlocking sheet piling; or combinations of these methods.

.06 Both of the above practices can be difficult, expensive, and not necessarily effective insofar as thermal protection of the service is concerned. As the frost depth increases in these conditions, the difficulty and expense of installing the water works to the required depth also increases.

3.1.2 Sanitary Sewers

.01 Conventional practice when installing sanitary sewers is to provide gravity flow from the basement of the building being serviced to a gravity collector system. At the high point in the system the collector sewer is generally in the order of 2.5 metres below grade. This depth is, in most instances, adequate to prevent freezing/glaciating of the sewage and to prevent any pockets from forming in the gravity line due to frost heave.

.02 In areas with rock or a high water table condition, the installation practices have generally been identical to that outlined above for watermains.

3.1.3 Watermains and Sanitary Sewers in Parallel

.01 MOE Policy 08-02-01 governs the separation of sewers and watermains. This policy and its associated guidelines are contained in Appendix F.

3.2 DIFFICULTIES ASSOCIATED WITH CONVENTIONAL PRACTICES

3.2.1 General

.01 The fact that the cost to install any proposed servicing system may be so high as to make it economically unfeasible can be a difficulty in itself.

.02 This situation generally occurs when the services are to be installed in an area that is subject to adverse conditions such as severe climate, remoteness, the presence of rock or a high water table condition or a combination of same.

.03 In this section the design, construction, maintenance and economic problems associated with conventional design in areas subject to adverse conditions will be discussed briefly.

3.2.2 Water Distribution

.01 There are two basic factors that must be considered when a water distribution system is being proposed. One is the financial aspect (i.e., capital and O/M) of the system and the other is the design criteria to be applied. Although the capital cost of a system is of prime importance, one cannot ignore the ongoing cost of O/M, which in many instances is a significant burden that can be reduced by appropriate design criteria.

.02 Unfortunately, when utilizing conventional design and installation practices, the above two factors are often contradictory. As the degree of difficulty of installing the watermain increases, so also do the costs. In areas subject to adverse conditions, the degree of difficulty of installation will always be higher and, accordingly, so will the installation costs.

.03 Experience has shown that where a water service is installed in an area composed predominantly of rock, the most common problem utilizing conventional practice has been the improper selection/application of frost depth penetration figures. These figures have either been chosen incorrectly or misapplied. In either case, the net result has been the all too frequent freezing and/or fracturing of pipes, and an associated increase in operating, maintenance and capital costs to repair or replace same, not to mention public inconvenience.

.04 Problems can arise when frost depth penetration values were applied without an adequate factor of safety in an effort to minimize, as much as possible, the high cost of excavation and hence watermain installation costs.

.05 The same situation occurs, to a lesser extent, for watermains that have been installed in areas with high water table conditions.

.06 Due to the small size of the pipe and the fact that the water is not generally kept flowing at all times, the water service connection is the most common place where freezing will occur. It is not uncommon practice to alleviate this problem by bleeding individual services by leaving a tap running in the individual home. In the past, the practice of bleeding was not viewed as a serious problem since the cost of producing water was not felt to be high. However, with increased construction and energy costs, etc., the practice of bleeding places an extraordinary burden on water supply facilities (i.e., 2600-3100 L/home) and, in the majority of instances, on the sewage collection and treatment facility, since the bleeder flows are usually discharged to the sanitary sewer system.

3.2.3 Sanitary Sewage Works

.01 Similar to the situation described previously for watermains, as the degree of difficulty of installation of the sanitary sewer increases, so also does the cost.

.02 In areas with a high water table, not only are the installation costs high, but in addition, infiltration into the system through pipe and manhole joints and private services continues to be a problem in many installations. Trying to effect repairs to an existing system installed in an area with a high water table is also difficult and expensive.

.03 In areas where the frost depth penetration is high, especially if rock is predominant, the need to install the sanitary sewer below the frost zone to prevent the pipe from freezing and to prevent any damage to the pipe through frost heaving greatly increases the installation costs. Many times this situation has necessitated the installation of the sewers below the depth normally required for gravity flow from the basements of the buildings being serviced.

.04 In some areas, the development density of the lots may be so low as to make sanitary sewer servicing unfeasible due to the high installation costs per lot. The use of septic tanks has been practiced in many of these situations. However, in an area where the presence of rock associated with very little overburden is the predominant feature, the use of septic tanks is generally unacceptable and the individual servicing costs utilizing a conventional sanitary sewer system is high.

3.3 RETROFITTING OF EXISTING SERVICES

3.3.1 General

.01 Based upon past experience and current technology, there are several improvements which should be applied to the upgrading of existing services in areas subject to adverse conditions.

.02 Most of the recommendations apply to areas where the winter temperatures are very cold, such as in the northern parts of Ontario. However, certain of the suggestion will be applicable anywhere the problems are encountered.

.03 These recommendations are supplementary to the appropriate sections of the MOE publication, "Guidelines for the Design of Sanitary Sewage Systems, Storm Sewers (Interim), Water Distribution Systems, and Water Storage Facilities.

.04 The group of formulae outlined in Appendix 'E', should be used to determine the depth of frost penetration. It is recommended that conditions of no snow cover be assumed for purposes of determining the maximum depth of frost. If the depth of cover over the watermains is not sufficient and/or the water is not kept moving, the system will freeze. In many cases the system may be located partially in the frost zone; however, as long as the water is kept moving (i.e., cold water is being replaced), the system will not freeze. At dead ends, fire hydrants, and some service connections, however, the freezing water may not be replaced and hence some method of frost protection must be provided.

.05 As indicated in Appendix 'O', an additional concern exists regarding the increased loading on the pipe due to frost. Accordingly, the Ministry would strongly recommend that the design of watermains and sanitary sewers in areas where the frost is experienced include an allowance for this frost loading.

3.3.2 Water Distribution

(i) System Layout

.01 In areas where frost depth penetrations are large and/or where the water service is located either partially or totally within the frost zone, the need for/desirability of eliminating deadend watermains (service connections are considered dead end watermains) is even more pronounced since any deadend watermains located within the frost zone will invariably freeze. Where it is not possible/viable to eliminate a deadend watermain, there are two possible solutions utilizing conventional design practices. The first is to insulate the watermain and the other is the replacement of the freezing water within the system by ensuring a constant flow of water through a recirculation pipe or a municipally controlled bleeder.

(ii) Insulation

.01 Rigid slab insulation placed above the water pipe has been used with some success as an alternative to burying the pipe below the frost zone. Its main application has been in attempting to correct existing freezing problems at hydrants and other dead ends and in situations where the cover over an existing watermain is reduced due to the reconstruction of the road or some other regrading situation.

.02 Although formulae used in the design of rigid slab insulation are presented, this does not mean that this method is recommended/endorsed. Rather, caution must be exercised in the use of flat slab insulation as some detrimental side effects may result from its use. A study undertaken by the Ministry (14) suggests that while slab type insulation materials have excellent insulating characteristics, they may in fact promote more rapid freezing and retard thawing in the zone insulated. It is suggested that slab type insulation only be used when there is a reasonable heat source available from below the pipeline (i.e. high groundwater) or the average water ambient temperature is relatively high.

.03 When rigid slab insulation is to be used to provide frost protection, the thickness of the slab must be carefully determined. The thickness is, in effect, replacing natural cover, thereby permitting reduced construction depths or providing additional protection.

.04 Based on available information (1), the thermal conductivity of polystyrene foam is approximately 0.036 W/m.K. The thermal conductivity of soils vary as follows:

Soil Type	Thermal Conductivity(1) W/m.K*
Peat, dry	0.07
Peat, thawed, 80% moisture	0.14
Peat, frozen, 80% ice	1.73
Peat, pressed, moist	0.70
Clay, dry	0.90
Clay, thawed, saturated (20%)	1.6
Clay, frozen, saturated (20%)	2.1
Sand, dry	1.1
Sand, thawed, saturated (10%)	3.2
Sand, frozen, saturated (10%)	4.1
Rock typical	2.2

* W/m.K = Watts/m^2/°K/m (ASTM E380 "Standard for Metric Practice").

.05 From the preceding, it can be seen that polystyrene is considerably more effective as an insulator than soil. In the opinion of the Ministry and based upon average conditions, the thickness of slab provided in an installation should be the equivalent of 25 mm for every 300 mm reduction in the depth of cover (i.e., 82 mm for every 1.0 m reduction).

.06 In determining the width of slab required, the Ministry, based on its own studies, recommends that the following formula be used:

$$W = 2(X-D)+d$$

where W = width of slab in metres
X = frost penetration depth in metres
D = depth of cover over insulation in metres
d = outside diameter of pipe in metres.

.07 It is recommended that the flat slab insulation be laid in 25 mm thicknesses with joints offset by half the width of board in progressive layers.

.08 As may be observed from the above formula for the width of insulation required, as the frost penetration depth increases, the width of insulation required also increases. It may, therefore, become more economical to provide an inverted U, or box type of slab insulation or use insulated pipe. The former two methods are extremely labour intensive and close field supervision is required to ensure the structural soundness of the U or the box.

.09 The alternative configurations for rigid board insulation are shown in Figure 3-1, Figure 3-2, and Figure 3-3.

(iii) Bleeders

.01 Bleeders should only be utilized as a last resort on existing systems, and should be under the strict control of the municipality/operating authority, regardless of their location.

.02 Bleeders associated with deadend watermains should be of a design similar to that shown in Figure 3-4 with the discharge of bleeder flow to an adjacent surface water course or ditch, if this is possible/feasible without creating nuisance icing conditions. If such a point of discharge is unavailable, the bleeder may be discharged to an adjacent sewer, provided the connection is as shown in Figure 3-4.

.03 Individual bleeders installed on private service connections should be located downstream of the water meter, where one exists. This bleeder should be equipped with a corporation seal and activated by authorized personnel only. This can be readily accomplished by the operating authority where individual meters are installed, as the meter reading can be scheduled to coincide with activation/de-activation of the bleeder in fall and spring. Figure 3-5 illustrates one alternative for a controlled private service bleeder. Another alternative is a factory manufactured automatic flow control/balancing valve.

(iv) Service Connections

.01 Service connections are the most common point where freezing will occur within any municipal distribution system. There are several contributing factors such as:

(a) the water service is, in essence, a deadend watermain subject to prolonged periods (i.e., overnight) of no-flow, thereby resulting in excessive cooling of the water;

(b) inadequate installation depths because of the cost, to the homeowner, of excavating in rock and/or in a zone of excessive frost depth.

.02 It has also been demonstrated that individual homeowners will not tolerate the repeated freezings of their service connection because of the associated inconvenience and cost of thawing. The net result is that the homeowners leave a tap running (i.e., an uncontrolled bleeder).

.03 The use of uncontrolled bleeders cannot be tolerated within a system since it imposes an unnecessary hydraulic load on both the water and sewage works facilities.

.04 In instances where repeated problems with freezing services have occurred or uncontrolled bleeders are in use to prevent freezing, several alternatives are available to reduce the problem. These alternatives include but are not limited to:

(a) re-laying of the entire service connection at an adequate depth of cover;

(b) replacement of the entire service connection with a new service connection installed in a pre-insulated service duct, with thermostatically controlled heat tracing if required;

(c) provision of insulation over the existing service connection, with heat tracing if required;

(d) the installation of a municipally controlled bleeder similar to that shown in Figure 3-5.

.05 By far the preferred alternative, particularly in areas with deep frost penetration and rock trenches, is (b) above. While this alternative will, in most instances, necessitate a higher initial cost, it will provide a more reliable long-term economic solution to the problem.

.06 Alternative (d) is the least desirable, particularly when widespread problems are being encountered in the system, as it does result in a wastage of approximately 2160 L/service/day. However, it may be the most viable alternative where only occasional problems recur. When such a device is used, it is strongly recommended that the bleeder installation be accompanied by a domestic meter.

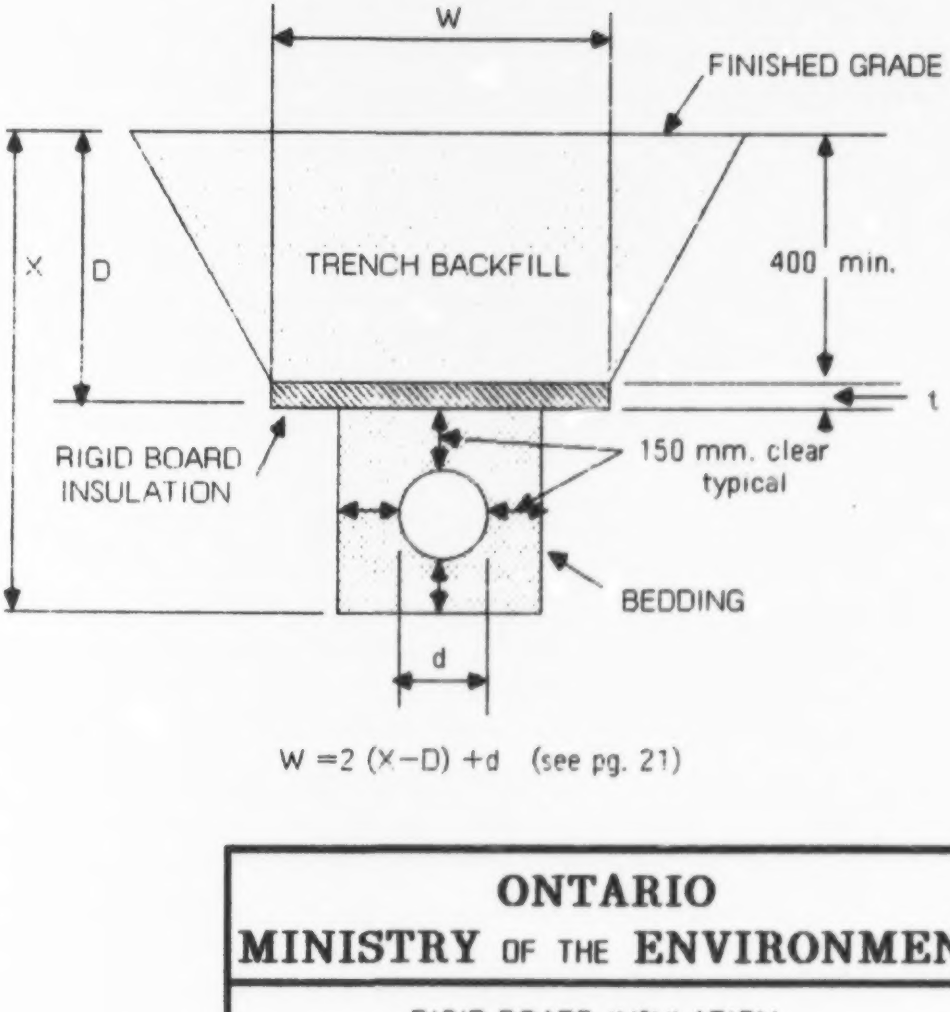
3.3.3 Sanitary Sewers

.01 There does not appear to have been any significant problem with freezing of gravity sewers, service connections or forcemains in the same way that watermains and water services freeze.

.02 As noted in Section 3.1.2 and Appendix O, frost has been found to exert considerable load on a buried conduit. In addition, MOE studies (7) have shown frost action can separate the sections of a pre-cast manhole if the sections are not strapped.

.03 There would appear to be little that can be done to an existing sewer system to protect it from the increased loads due to frost, although some studies suggest that slab insulation above the pipe will distribute the load.

.04 The aforementioned studies by MOE (7) have developed a formula for sizing the straps, etc. to prevent heave of the manhole sections. Where existing manholes have separated and are permitting extraneous flows, etc., the manholes should be grouted and/or reset and straps installed on the inside of the manhole to prevent any further movement. The recommended design procedure for the straps is contained in Appendix P.

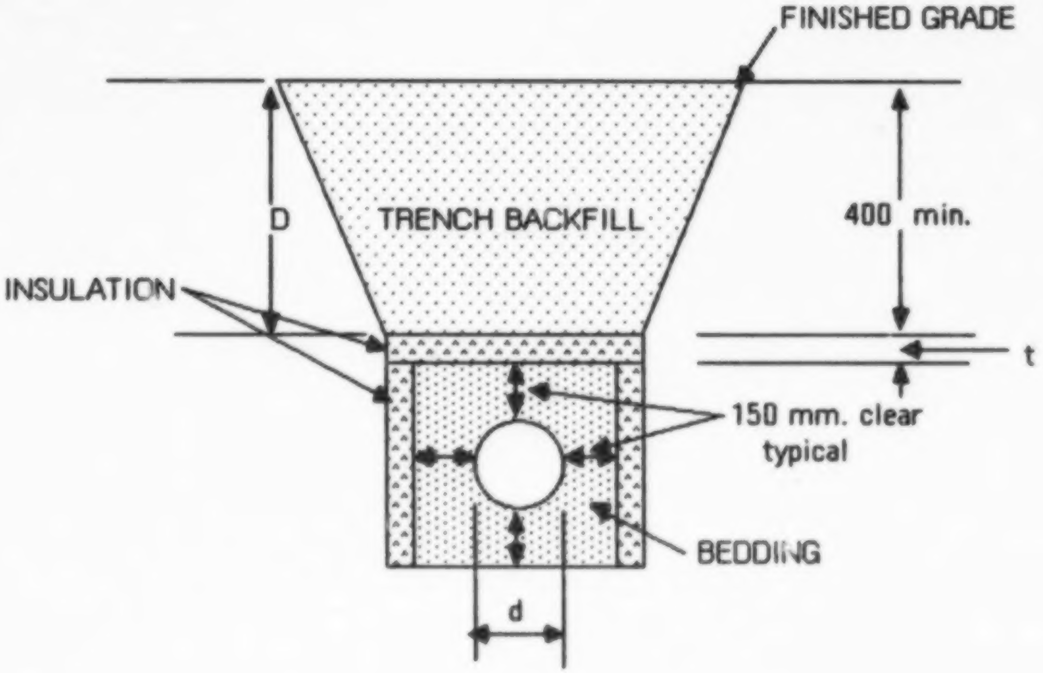

W
FINISHED GRADE
X
D
TRENCH BACKFILL
400 min.
t
RIGID BOARD INSULATION
150 mm. clear typical
BEDDING
d

W =2 (X−D) +d (see pg. 21)

ONTARIO
MINISTRY OF THE ENVIRONMENT

RIGID BOARD INSULATION
SLAB TYPE

FIG.3−1	REVISED SEPT. 1985	DATE:JULY 1985


FINISHED GRADE
D
TRENCH BACKFILL
400 min.
INSULATION
t
150 mm. clear typical
BEDDING
d

NOTES: NOTES:

1. Calculate W= 2(X−D) +d .
2. Calculate perimeter of inverted U .
3. Using larger dimension from above construct an open bottom box comprising three equal width pieces in which the pipe is centred.

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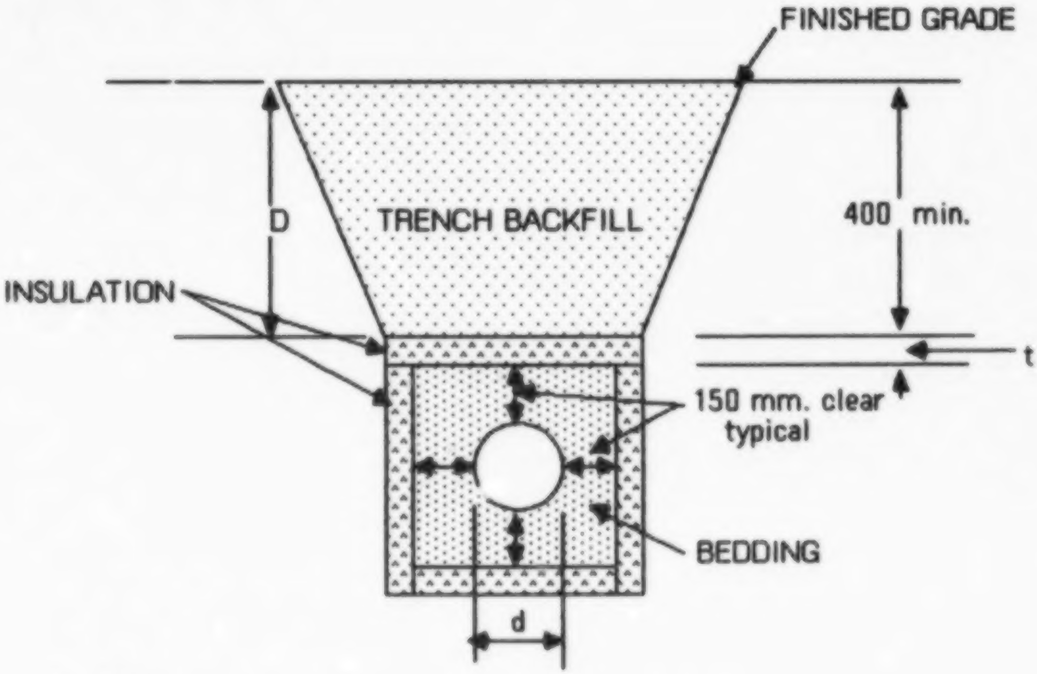
RIGID BOARD INSULATION
INVERTED "U"

FIG.3−2

DATE:JULY 1985


FINISHED GRADE
D
TRENCH BACKFILL
400 min.
INSULATION
t
150 mm. clear
typical
BEDDING
d

NOTES:

1. Calculate W= 2(X−D) +d.
2. Calculate perimeter of insulation.
3. Using larger dimension construct a box comprising four equal width pieces in which pipe is centred.

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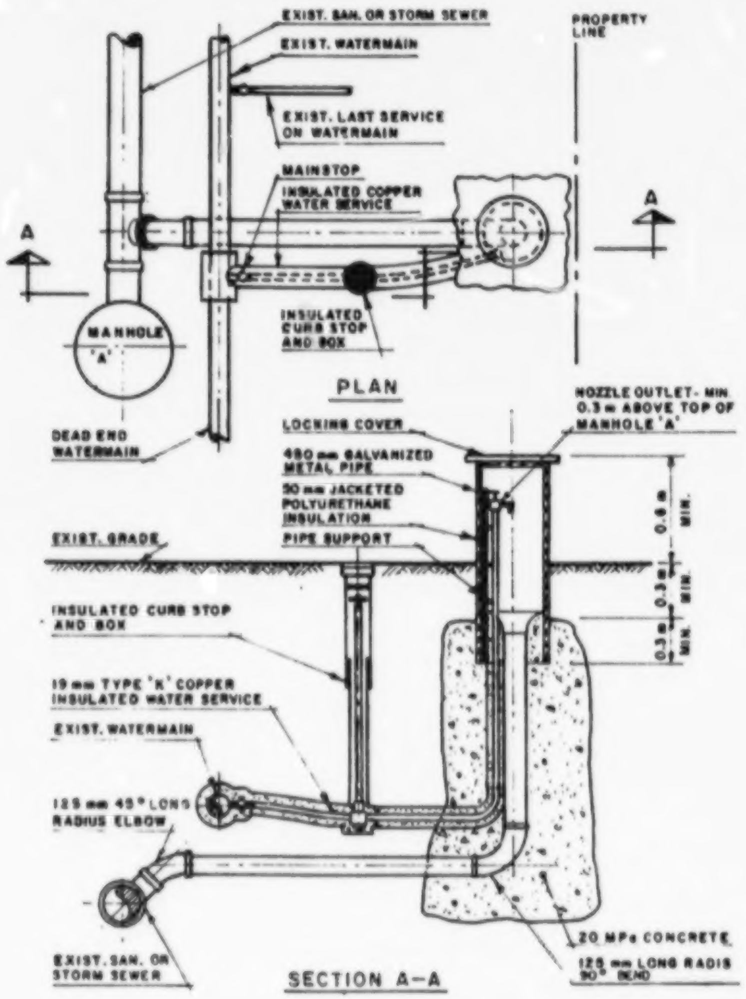
RIGID BOARD INSULATION
BOX

FIG.3−3

DATE:JULY 1985


EXIST. SAN. OR STORM SEWER
EXIST. WATERMAIN
PROPERTY LINE
EXIST. LAST SERVICE ON WATERMAIN
MAINSTOP
INSULATED COPPER WATER SERVICE
A
A
MANHOLE 'A'
INSULATED CURB STOP AND BOX
PLAN
DEAD END WATERMAIN
NOZZLE OUTLET- MIN 0.3 m ABOVE TOP OF MANHOLE 'A'
LOCKING COVER
480 mm GALVANIZED METAL PIPE
50 mm JACKETED POLYURETHANE INSULATION
PIPE SUPPORT
EXIST. GRADE
0.6 m MIN.
0.3 m MIN.
0.3 m MIN.
INSULATED CURB STOP AND BOX
19 mm TYPE 'K' COPPER INSULATED WATER SERVICE
EXIST. WATERMAIN
125 mm 45° LONG RADIUS ELBOW
20 MPa CONCRETE
125 mm LONG RADIS 90° BEND
EXIST. SAN. OR STORM SEWER
SECTION A-A

ONTARIO
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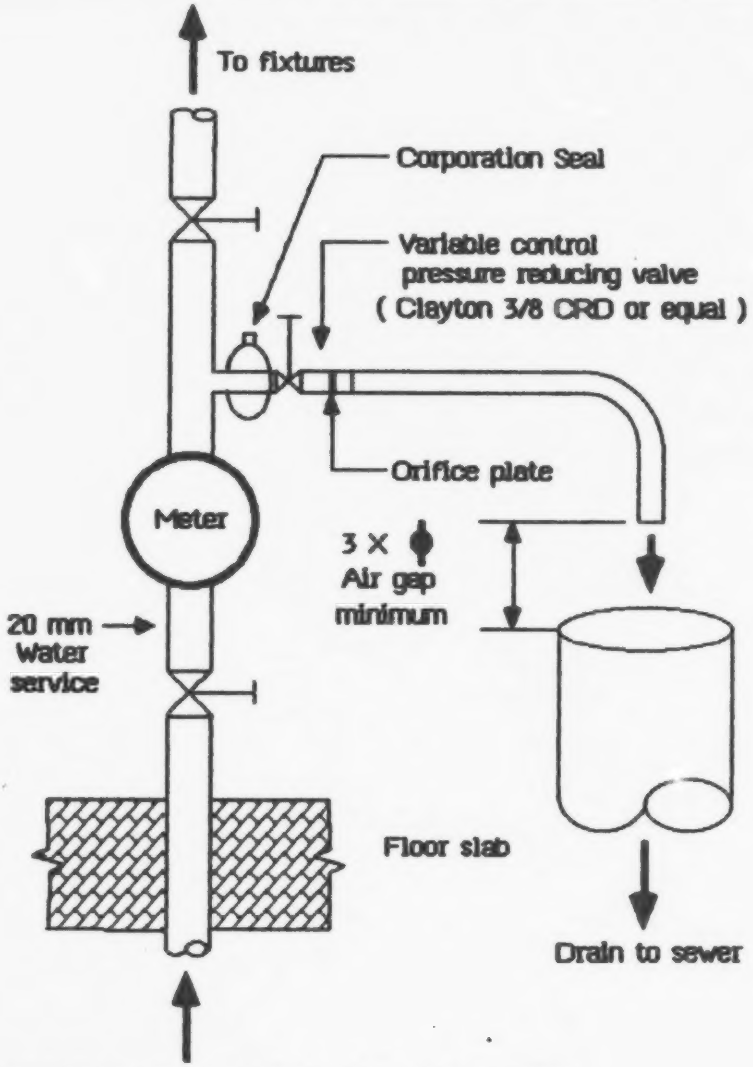
MUNICIPALLY CONTROLLED
BLEEDER

FIG. 3-4

DATE: APRIL 1984


To fixtures
Corporation Seal
Variable control
pressure reducing valve
(Clayton 3/8 CRD or equal)
Orifice plate
Meter
3 X ϕ
Air gap
minimum
20 mm
Water
service
Floor slab
Drain to sewer

NOTES : 1) Air gap must be equivalent to twice the diameter of the discharge pipe from the bleeder

2) The orifice plate should be designed for a bleed rate of 1.5 L/m .

3) The variable control pressure reducing valve is essential to ensure a constant bleed rate regardless of system pressure .

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SCHEMATIC OF TYPICAL DOMESTIC
BLEEDER

FIG. 3-5

DATE: APRIL 1984

4.0 ALTERNATIVE DESIGN PRACTICES

4.1 INTRODUCTION

.01 The previous sections have discussed, in a general way, the various factors/adverse conditions which impact upon communal water and sewer services. In addition, some suggestions have been made with regard to the upgrading of existing systems to reduce the impact of these factors on the systems, and hence inconvenience to both the operating authority and the public.

.02 Improved public awareness and education respecting the cost of services and the need for conservation dictates that alternate solutions and technologies be considered in the design of new works.

.03 This section will discuss some, but not all, of the alternate technologies/approaches that should be considered, particularly in areas subject to adverse conditions of climate and/or geology.

4.2 GENERAL

.01 In general, the cost of installing water and/or sanitary sewer services increases as the depth of bury increases. As discussed in Section 3.2, in areas that are subject to the effects of adverse conditions (such as the presence of rock, extreme frost, or a high water table) the costs would be much greater as the depth to which these services need to be installed increases.

.02 One obvious way to reduce the installation cost, and hence the servicing cost, is to employ alternate technologies.

4.3 THERMAL CONSIDERATIONS

.01 The basic problem that must be addressed for a system to be located either partially or totally within the frost zone is the impact of frost. If freezing or frost damage occurs, not only will service be interrupted, but structural damage and public inconvenience will occur.

.02 Appendix 'Q' provides several example calculations of the various conditions which should be considered when freezing conditions are encountered.

.03 With the information presented in Appendix 'Q', it is possible to install services within the active frost zone by utilizing methods and materials to reduce and/or replace the heat losses that would cause the liquid within the servicing system to freeze.

4.4 SHALLOW BURIED SERVICING SYSTEMS

4.4.1 General

.01 As suggested in Section 4.2, areas that are subject to adverse conditions may be more practically and/or economically serviced via an alternate technology. One such technology is a shallow buried pre-insulated piping system.

.02 By 'shallow buried' we mean a system that is partially or totally within the frost zone (i.e. cover only for physical protection) and by 'insulated' we mean reducing the heat loss from the pipe by applying various amounts of insulation to the buried pipe. The amount of insulation will be determined using the equations outlined in Appendix 'Q'.

.03 In addition to the insulation, varying amounts of heat can be added to the service by inducing circulation or adding supplementary heat (i.e., heat tracing, hot water, etc.).

.04 The use of shallow buried servicing systems is not new. It has been practiced in northern jurisdictions such as the Northwest Territories, the Yukon, and Alaska for many years and the "state-of-the-art" is well advanced.

.05 The system which appears to have gained the most acceptance is the "factory fabricated, pre-insulated, flexible piping system".

4.5 WATER SYSTEM DESIGN

4.5.1 General

.01 The fundamental concepts of water distribution system design, appurtenances, etc. should follow the recommendations contained in the MOE "Guidelines for the Design of Water Distribution Systems" and "Guidelines for the Design of Water Storage Facilities".

4.5.2 System Layout

.01 The designer and the owner/operator should maintain a relatively open approach insofar as routing flexibility/layout are concerned. While straight line grid systems are preferred, routing flexibility should always be in mind, since it may be possible to "skirt" an adverse condition such as exposed rock by utilizing unconventional alignments. For example, it is "normal" practice to construct the watermain within the road allowance and generally within the travelled/plowed portion of the road. Invariably, frost penetration within this area is substantially higher than in the unplowed areas, and experience has shown that watermains located within the plowed portion of the road and any service connections which must cross the road are more likely to freeze. It is therefore advisable to consider an alternate alignment such as the ditch line of the road where it is not plowed, or the use of parallel front yard or backyard easements.

.02 If the option of front yard or backyard easements is utilized, many of the problems which may be anticipated with respect to obtaining the necessary easements could quite possibly be overcome through adequate and proper public relations and public meetings. Specifically, in allowing an easement, a homeowner is not giving up the right to ownership of the property involved; rather, it simply means that the municipality/operator is granted certain rights such as the right to construct a watermain and enter the property for the purposes of maintenance, with the understanding that any damage incurred to the property will be rectified by the person to whom the easement is granted. Typical examples of such easements and agreements would be easements granted to utilities such as Bell Telephone, the Gas Company, or the Hydro Authority.

.03 In areas where the water service will be located either partially or totally within the frost zone, the need for eliminating deadend watermains (service connections are considered deadend watermains) is even more pronounced since any deadend watermains located within the frost zone will invariably freeze due to the lack of movement/circulation of the water. Where it is not possible/viable to eliminate a dead end watermain, there are several alternatives available to reduce the probability of frost problems.

.04 Among the alternatives available are:

(a) insulation of the water service with slab type insulation with or without a circulation line;

(b) construction of the facility with a pre-insulated pipe package with heat tracing or an external thaw tube;

(c) design of the system to include an induced flow via either a recirculation system or as a last resort, a municipally controlled bleeder;

(d) a combination of the above.

.05 As has been noted in Section 3.3.2 (iii), bleeders should only be utilized as a last resort, be under the control of the municipality and when discharged to a sewage works be in accordance with Figure 3-4. As an alternative, and where a bleeder is the only alternative, one may wish to use the last private connection as the "bleeder", thereby solving two problems at once and providing for a simpler bleeder installation and maintenance (i.e., bleeder in a controlled, heated environment).

4.5.3 Insulation of Watermains and Services

.01 Based on the experiences of others (1, 2, 3, 9, 12), it is the opinion of the Ministry that the preferred alternative for a shallow buried, thermally insulated water distribution system is that employing a factory-fabricated, pre-insulated package type piping system. These systems are fabricated under factory controlled situations, thus providing high quality assurance. Systems where the insulation is applied in the field only achieve the required quality when the site conditions are perfect (which seldom, if ever, happens).

.02 There are basically three options for a factory-fabricated, pre-insulated flexible piping system:

(a) pre-insulated piping system without heat tracing or an external thaw tube;

(b) pre-insulated piping system with heat tracing; and

(c) pre-insulated piping system with an external thaw tube (NPS-1).

.03 The three types are illustrated in Figure 4-1.

.04 Similarly, there are two basic types of factory-fabricated pre-insulated service connection pipe:

(a) the individually insulated service connection (either with or without heat tracing);

(b) the duct pipe with a single service connection inserted within the duct (either with or without heat tracing).

.05 The two types are illustrated in Figure 4-2.

.06 The heat tracing cable for either of the above pipe systems can have two functions, depending upon the design requirements: it can serve to thaw the line once it has frozen (passive tracing - no thermostat), or it can be used to prevent the water in the pipe from freezing (active tracing - thermostatic control).

.07 It should be noted that the insulation and its jacket material must be able to withstand the trench and service loadings without subjecting the service or duct pipe to excessive deflections or compression. For this reason, the insulation should be of a higher density than the surrounding soil.

4.5.4 Pipe Materials

.01 At this point in time, the Ministry has no reason to believe that any of the alternate materials listed in the Ontario Provincial Standard Specification should not be used, provided all of the factors relative to the design are considered. Among these factors is the ability of the pipe joint to maintain "zero" leakage over the long term when subjected to frost action and the ability of the pipe material itself to resist structural damage/failure when subjected to inadvertant freezing and/or frost action such as frost heave or differential loading. The experience of others and evaluations conducted by others (1, 2, 3, 9, 12) suggest that the preferred shallow buried, pre-insulated piping material is high density polyethylene (HDPE) with an HDPE external jacketing for moisture protection of the insulation.

.02 This preference is based upon the following factors:

(a) A shallow buried system , by its nature, will be subject to frost heave as it is constructed within the frost zone. Accordingly, the pipe material must be capable of withstanding variable loading and movement without failure of the "packaged" pipe (i.e., jacketing, pipe joints, etc.).

(b) The insulation material most commonly employed in a factory pre-insulated piping package is polyurethane foam. In a report prepared by the National Research Council Canada (18) it is noted that:

i) Polyurethane is best used in a cool dry environment;

ii) A good design will ensure its protection from extremes in temperature and from becoming wet;

iii) A vapour barrier will be provided that will keep excess moisture from entering the material and condensing or freezing in colder parts of the foam;

iv) Polyurethane does not have good freeze-thaw resistance. If the material is wet and is subjected to freeze-thaw cycles it may disintegrate after only a few dozen cycles.

The report concludes by noting that while it has pointed out the negative aspects of polyurethane insulation, the material has many positive features and that an understanding of the negative aspects is essential in defining the correct application.

.03 Figures 4-1, and 4-2 show typical configurations for factory-fabricated pre-insulated pipe. Each of these "packaged" pipes has the following basic components:

(a) Carrier Pipe - High Density Polyethylene to Section MOE 02660, Clause 2.5.

(b) Insulation - Factory applied polyurethane foam with a density of 0.045 to 0.067 g/cm^2 (ASTM D1622).

(c) External Jacket - High Density Polyethylene/ extruded monolithic or counterwound double layer tape hot applied tape - minimum 45 mil finished thickness.

(d) Heat Trace Cable (Optional) - Parallel resistance circuit type (constant watt) to CSA LR 24346 or CSA LR 42612-1 or UL E56615 project 74CH781 - wattage to be determined for the specific application.

(e) Thermostatic Controller (with heat trace) - Solid state proportional tracing CSA approved with dual thermistor controllers with a high temperature trip set at 29°C to detect cable overheating; or

- Dual mechanical thermostat for zone type tracing CSA approved with two integral thermostats, one to control the tracer, the other to prevent overheating.

(f) External Thaw Tube - High Density Polyethylene to MOE 02660, Clause 2.5.

.04 MOE experience has shown that the purchase of a pre-insulated pipe package should be from a single source in order to reduce the probability of problems, and disputes etc. This single source should supply and guarantee the total package including carrier pipe, insulation, jacketing, heat trace cable and thermostatic controls. In addition, the single source should be required to provide in-field service and technical expertise.

.05 MOE experience and the experience of others suggests that the provision of active heat tracing is not generally required on gravity sanitary sewers or large diameter watermains and forcemains (i.e., diameter above NPS-6) and may not be required on smaller diameters within the public right-of-way, provided the liquid is kept moving. In the opinion of the Ministry, a minimum acceptable time-to-freeze of approximately 96 hours, as determined from

Appendix Q, would be considered an acceptable level of risk, however, the final decision in this regard rests with the designer and the owner/operator.

.06 However, where the time-to-freeze is less than 96 hours or a deadend watermain/water service connection is involved, it is recommended that active heat tracing be provided. By active heat tracing, it is meant that a thermostatically controlled (solid state) heat trace cable will be provided.

.07 Where it is determined that it is necessary or advisable to provide active heat tracing on main lines, as opposed to service connections, the designer should acquaint himself with items such as:

a) The spacing of "power points" which is dependent upon heat tracer length capability;
b) Special manhole requirements;
c) Local hydro metering protocol.

Of particular importance is c) above as the local authority may utilize a stepped billing rate which will have a significant impact on power costs.

.08 When the time to freeze is greater than 96 hours, it is recommended that a passive thaw system be provided. By passive, it is meant that either a manually activated heat trace cable or an external thaw tube is provided to facilitate thawing of the service should it freeze. A passive system would only be activated when the freezing had occurred.

.09 Based on studies by others (9), the alternative of an external thaw tube with heat transfer cement would be the preferred passive system for the following reasons:

- (a) lower initial capital cost;
- (b) flexible use;
- (c) lower operating cost;
- (d) substantially shorter times to thaw the frozen line

The disadvantages with this type of system are:

- (a) it is manual;
- (b) provision must be made for access to the thaw tube;

.10 The thawing liquid must be an appropriately mixed antifreeze solution of propylene glycol (not ethylene glycol as it is toxic).

.11 Typically, the equipment necessary for thawing with an external thaw tube system is:

- (a) a 3.00 kW capacity electric heating unit weighing approximately 7.3 kg equipped with a flow controller rated at 2 L/m on the outlet side of the heater unit;

- (b) a source of antifreeze solution with a reservoir (poly pail), hoses and a pump to pump the heated solution through the thaw tube/solution heater "loop".

Packaged hot water thawing equipment is available from a number of suppliers.

4.5.5 Service Connections

.01 All new water service connections which are installed within the frost zone should be constructed in a pre-insulated HDPE duct c/w active heat tracing and a thermostatic control. Bleeders should not be employed as a method of freeze protection on new services.

.02 In many instances, even where there is theoretically sufficient cover, particularly in rock, a similarly protected service should be provided.

.03 Considerable controversy surrounds the matter of heat tracing; i.e., the type of cable, the cable jacketing and the need for thermostats, etc. In the opinion of the Ministry, the following factors should be considered.

(a) Type of Heat Trace Cable - there are basically two types of heat trace cable available: parallel resistance/constant watt type and self-limiting type. Both options are acceptable forms of heat tracing; however, as with any "comparable" product, each has its own limitations insofar as application suitability is concerned.

Package suppliers to date have, in some instances, shown a reluctance to offer self-limiting cable with their package. This concern does not appear to relate to the suitability of this type of cable for heat tracing in general, but to its suitability for use with an HDPE pipe, particularly in a pressure application (i.e., hot spots/stripes and reduction of rated pressure).

(b) Cable Jacketing - Various materials are used for jacketing/coating of parallel resistance/ constant watt cables. These materials include elexar*-coated cable and teflon*-coated cable. Both cables have been used with success in Ontario and other jurisdictions. Factors to consider in assessing the alternative cable jackets include moisture resistance and minimum/ maximum temperature operating characteristics. While a teflon jacketed cable is generally more expensive on initial capital cost, its greater moisture resistance and temperature range will generally translate to a longer service life.

(c) Thermostats - Dual controller thermostats should be provided on all heat trace cable installations. Solid state proportional trace dual thermistor controllers with a high temperature trip are preferred. However, dual mechanical thermostats may be considered on house service connections. In reviewing the acceptability of the mechanical units the designer should consider that, while the unit is less expensive, the capilliaries are non-adjustable (i.e. fixed length), the mechanical thermostat is not as accurate and the thermistors cannot be installed independent of the control box.

The thermostat will limit cable operation/energy consumption to when it is required, safeguard both the cable and the duct system against overheating/damage, and theoretically increase cable life. Manual forms of activation such as an

*Registered Trademark

on-off switch, while initially less expensive, will generally:

(i) reduce cable life;
(ii) result in freezing if not turned on or consume unnecessary energy if left on all the time;
(iii) result in unnecessary over-heating of the system.

In summary then, it is the recommendation of the Ministry that all heat-traced installations include a solid state thermostatically-controlled, teflon-coated parallel resistance constant watt cable system.

4.5.6 Installation Details

.01 Figure 4-7 shows typical pre-insulated pipe installation details. It will be noted that the fundamentals of pipe installation are no different for this type of pipe than for a conventional pipe installation. However, several additional features should be included on shallow buried, pre-insulated systems. These are:

(a) Pre-insulated pipe should not be buried with less than 1.2 m cover when it will be subjected to vehicular (H-20) loadings, (i.e., driveways and highway crossings) without the provision of additional protection for the pipe. This protection can take the form of either a metal jacketed pre-insulated pipe or a HDPE jacketed pipe installed within a CSP culvert section(s).

(b) A nominal 50 mm x 200 mm warning board should be placed 150 mm above any pre-insulated pipe with less than 1.2 m cover in order to afford protection to the pipe and warn excavators.

(c) When the pipe is being installed in a rock trench on a long radius deflection/curve, sand bags should be placed between the pipe and the trench wall as shown in Figure 4-8.

(d) The pipe design should include a check for buoyancy in areas where the pipe will be located at or below the groundwater table.

(e) The pipe should be "snaked" in the trench in order to allow for expansion and contraction.

4.5.7 Fittings and Appurtenances

.01 When a shallow buried, thermally insulated type system is proposed, special consideration must be given to both the type of fitting proposed and its proper installation.

(i) Valves

Low thermal conductivity valve box materials with valve system extension pieces should be used such as shown in Figure 4-5.

(ii) Chambers

Where it is necessary to provide valve or meter chambers etc., the chambers should be adequately insulated, provided with frost covers in the access hatches, the pipe proper should be insulated and, when necessary, heat traced.

(iii) Bends and Tees

.01 Where ductile iron fittings are used with mechanical joint fittings, restraining type glands should be utilized as opposed to concrete thrust blocks to better facilitate either factory applied or field applied insulation. The insulation should be coated with a suitable moisture barrier.

.02 High density polyethylene pipe can be adapted to his type of system through the use of thermally butt fused end flanges connected to flanged to plain end ductile iron pipe filler pieces.

.03 Polyethylene pipe can also be connected utilizing special pipe ends that can be used to join together individual pieces of pipe or fittings with Victaulic Couplings. Typically, however, these specials should only be used in repair situations.

(iv) Hydrants

.01 Hydrants and their leads are essentially a dead end watermain and must, therefore, be accorded special attention. The importance of this special attention is reinforced by the necessity of maintaining the hydrant operational/frost-free year round.

.02 The simplest and most effective way of protecting the hydrant assembly is to locate the watermains off the travelled road allowance (i.e., within the ditch line or easements), and close couple same to the tee and shut-off valve assembly and insulate the barrel. (Figure 4-9)

.03 When conventional type hydrant leads are used, the lead and valve assembly as well as the barrel should be insulated. (Figure 4-10)

.04 On a conventional "long" lead, deepening of the lead relative to the watermain should be avoided as the cost of the special insulated fittings, etc. (i.e., elbows) is high.

.05 The hydrant barrel should be provided with a frost isolating gasket between the hydrant barrel and the boot.

.06 When the take-off from a line has a diameter greater than half the diameter of the line, the take-off should be accomplished via a line size tee and the step down provided on the take-off through a standard reducer. This arrangement will reduce the number of "special" pre-insulated half shells required.

4.5.8 Single-Pipe Recirculation System

.01 The single-pipe recirculation system is recommended for small northern communities, particularly where the majority of the community is founded on rock. This system consists of one or more uninterrupted loops or sub-loops originating at a recirculation facility and returning to that facility.

.02 Planning and layout of such a system should be such as to minimize the length of pipe required and, in turn, minimize energy losses.

.03 This system allows for positive simple control of the distribution system via the installation of flow, pressure and temperature monitoring on the return line(s) at the recirculation facility. The rate of pumping/recirculation is controlled by the supply and return temperatures. The actual variation in rate can be accomplished via either the use of a pressure reducing, pressure sustaining type valve; turning additional pumps on or a combination of these two.

.04 Supply temperatures should be in the order of 4-7°C with return temperatures between 1-2°C. In some instances, pretempering (i.e. pre-heating) of the supply water may be required. This can be accomplished, when necessary, via the use of a supplementary water heater (gas or electrical).

.05 An obvious disadvantage to this type of system is that, as the length of the loop increases, the loss of service increases in case of a shutdown due to a problem anywhere along the line. In practice, this need not necessarily be a problem as short loop links can be installed at strategic locations to break the main loop. These links are valved off and the pipe left empty. In the case of an emergency, these links can be opened up to reroute the flow of water and possibly isolate the break.

.06 The single-pipe recirculation system can be designed to supply water in the normal "return" line as well as the supply line under fire conditions. For this reason, the return line does not decrease drastically in size.

.07 The recirculating facility can be located at the source or in a separate pumping facility, or a combination of the two.

.08 By planning community growth in a dense circular pattern, maximum efficiency can be made of this method of servicing. The worst situation would be a long strung-out community with the facility at one end. This usually ends up increasing pumping requirements and duplication of lines.

.09 Back-of-lot mains are preferred if possible. If the mains are placed in the street, the appurtenances (valve boxes etc.) are subject to physical damage.

.10 Placing the mains at the rear lot line reduces service line connections and permits service lines of equal length on both sides of the main. With mains in the road allowance, usually to one side, services are of unequal length. There is a significant saving to the homeowner in this method of servicing through reduced restoration/installation costs etc.

11. A further advantage of mains located along the rear lot line is that the manholes containing water line valves and hydrants, freeze protection controls, etc., can be elevated in cylindrical shape approximately 1.0 m above grade. This results in easier access during the winter as the immediate area around the elevated manhole is often blown clear of snow.

4.6 SANITARY SEWER SYSTEMS

4.6.1 General

.01 The fundamental concepts of sanitary sewer system design, layout, appurtenances, etc. should follow the recommendations contained in the MOE "Guidelines for the Design of Sanitary Sewage Systems".

4.6.2 System Layout

.01 In the laying out of a gravity sanitary sewer system in areas where frost depth penetrations are great and/or other adverse conditions exist, consideration should be given to alternate routing of the sewers as has been suggested for watermains; (i.e., off the traveled/plowed portion of the road).

.02 Present experience in Ontario would suggest that there has not been any significant problem with ice/freezing of gravity sanitary sewers (i.e., the contents). However, problems have been experienced due to frost action through separation of precast manhole sections, thereby allowing extraneous flows. In addition, studies undertaken by others (10, 11, 16 and 17) suggest that frost induces a significant additional load on a buried conduit. If this additional load is not addressed in the design phase of a project, the result may well be significant quantities of extraneous flow through broken pipe sections and/or disrupted joints.

.03 In view of the preceding, it is recommended that all gravity sewer system designs include the provision of frost straps on all manholes as per Appendix 'P' and that all pipe designs reflect the increased loading that will be experienced through either improved bedding or increased pipe strength (Appendix Q).

.04 As is noted in Section 3.1.2 and 3.2.3, the typical minimum depth of a gravity sanitary sewer is 2.5 m in order to facilitate gravity basement drainage and/or protect the sewer from frost. These depths, particularly in adverse soil conditions such as rock or high groundwater can significantly affect the cost of the sewers and, in some instances, contribute to extraneous flow problems. It may be advisable in such circumstances to design and construct the system such that gravity drainage is only provided for the first floor and up. In assessing such an alternative, however, it is essential that the following factors be considered:

(a) The presence or absence of basements in the existing dwellings;
(b) the extent of "finishing" in an existing basement;
(c) the presence or absence of fixtures in the basement;
(d) the need for a solids handling sump pump in the basement should the basement contain fixtures.

4.6.3 Alternate Sewage Collection Systems

.01 The cost of providing communal sanitary collector sewers increases significantly in areas subject to adverse conditions, particularly rock or high groundwater conditions. In many instances the cost is beyond the capability of the service area.

.02 Also, the cost of the building sewers on private property in many instances is beyond the capability of the homeowner.

.03 In the recent past, several alternate methods of communal servicing have been introduced in Ontario and other jurisdictions with success. These alternates include vacuum sewers and pressure sewers.

.04 Appendix 'S' contains the Ministry's position respecting Alternate Technologies.

4.6.4 Vacuum Sewers

.01 It is not seen by the Ministry that a vacuum toilet system is to be widely used in the Province except in special instances such as the servicing of fair grounds, construction camps etc. However, the use of an on-line vacuum system may prove viable in some instances.

.02 Since the concept, design, and hardware associated with an on-line vacuum sewer system are proprietary in nature, the Ministry has made no attempt in these guidelines to provide specific design details/ guidelines. Rather, the following briefly describes the major components of an on-line vacuum sewer system. For specific design details, etc. it is recommended that contact be made with the Canadian licensee, Vacusan, Division of Euroclean Canada Inc.

.03 The on-line vacuum system interfaces with conventional gravity plumbing via an interface unit (Figure 4-12(a)/one per home). The vacuum sewers do not require continuous gravity fall. Air rather than gravity is used as a positive transport medium to overcome ground contours (Figure 4-13) with the vacuum induced via a vacuum collection station(s) (Figure 4-14).

.04 From the vacuum collection station, the raw sewage is discharged to the treatment facility or the balance of the collection system.

.05 In the design of any vacuum sewer system and in particular those subject to adverse conditions such as deep frost penetration, high ground water and/or flooding conditions, particular attention must be paid to the design and installation of the interface unit particularly if it is located outside the home. Care must be taken to ensure that the unit is not prone to flooding via either surface runoff or high water/flood conditions and that it is adequately protected against frost.

.06 It may be found that the use of a buffer type interface unit located in the basement of the serviced building is preferred in such instances. The buffer type unit (Figure 4-12(b)) consists of an atmospheric buffer tank with the activator and valve mounted on a metal plate above the buffer tank.

4.6.5 Pressure Sewers

.01 A pressure sewer system is essentially the reverse of a water distribution system. Where the latter generally employs a single inlet pressurization point and a number of user outlets, a pressure sewer system embodies a number of pressurizing inlet points and a single outlet (see Figure 4-15). The user input to the pressure sewer follows a generally direct route to either a treatment facility or a gravity sewer.

.02 There are two basic types of pressure sewer system; the Grinder Pump (GP) system and the Septic Tank Effluent Pumping (STEP) system. Both systems may be connected to existing household plumbing systems without modification to same, although neither system precludes modifications if they are deemed advisable. The major differences between the two systems' equipment is evident in Figures 4-16, 4-17, 4-18 and 4-19. Subtle differences also exist in the pressure main design method, the treatment systems required, the power requirements, etc. These differences will be discussed in later sections.

4.6.5.1 Grinder Pump (GP) Pressure Sewer System

.01 The Grinder Pump (GP) system consists of a holding tank that receives the sewage directly from the house plumbing and retains the sewage until enough liquid has been accumulated to allow the grinder pump to operate (typically 200 litres). The holding tanks are available in fibreglass, polyethylene, ABS and steel. The Ministry recommends that non-metallic tanks be utilized due to their corrosion resistance and relatively light weight. While a GP unit is vented through the existing building stack, experience would suggest that a second vent within 1.0 m of the unit is desirable to reduce any accumulations of potentially noxious gases; reduce the potential for negative pressures in the house plumbing under certain flow conditions or false starting of the pumping unit via increased air pressure in the pump well when large volumes are discharged to the unit.

.02 The grinder pump unit installed within the holding tank is either a submersible centrifugal type pump (Figure 4-16) or a progressive cavity screw-type pump

(Figure 4-17). The head-capacity curves for the two types of units is shown in Figure 4-20. Both types of units have been employed successfully in Ontario as well as in other jurisdictions.

.03 Typically, grinder pumps are 240 V, 1 ph, 60 hz and require a 30 amp circuit with motor sizes ranging from 0.75 kW up.

4.6.5.2 Septic Tank Effluent Pumping (STEP) Pressure Sewer System

.01 The Septic Tank Effluent Pumping (STEP) system consists of a conventional two-compartment septic tank into which sewage from the house plumbing is discharged. Settled sludge and scum are retained in the first compartment with clarified overflow to the second compartment. The effluent discharge in the second compartment is pumped, via a system of pressure sewers, to the point of disposal. Several effluent pumping arrangements exist, each of which employs a centrifugal pump. (Figures 4-18 and 4-19). The most widely installed option for the STEP system is that shown in Figure 4-19.

.02 Typically, STEP pumping equipment employs a 120 V, 1 ph, 60 hz pump with motor sizes ranging from 0.25 kW up. Amperage requirements vary from 15 amps up.

.03 Though various references suggest differing interceptor or septic tank capacities, the generally accepted average capacity required is approximately 3.8 m^3 per connection. The septic tank generally has 0.38 to 0.76 m^3 reserve capacity available because of the freeboard inherent in the construction of the tank. In Ontario, a 4500 L septic tank manufactured to CAN3-B66-M79 "Prefabricated Septic Tanks and Holding Tanks" should be provided.

.04 Experience has shown that the conversion of existing septic tanks is generally not advisable/feasible for the following reasons:

(a) the existing tank must be excavated and renovated/modified to permit the installation of the pumping unit c/w controls;

(b) the existing tank should be smoke/air tested to ensure there are no leaks and should be inspected visually to determine its structural integrity;

(c) the existing tile field must be severed to ensure no "backflow" of ground water;

(d) an access manhole must be provided in order to permit servicing of the pumping unit and/or controls, and the periodic pumping out of the tanks to remove accumulated sludges and scum.

All of the foregoing must be undertaken while the tank is in service.

4.6.5.3 Grinder Pumps vs STEPs

.01 In assessing whether to employ a GP system or a STEP system, the following factors should be considered:

(a) The size/adequacy of the existing hydro service and the cost of upgrading, if required.

(b) The topography of the service area and the resulting head/power requirement.

(c) Annual O/M costs. With a GP system, solids are ground up and pumped through the sewers to the point of disposal, whereas with a STEP system solids are retained in the septic tank and only clarified effluent discharged through the sewers. That is, with a GP system, maintenance of the pressure sewer piping system may be higher because of the solids content of the sewage. However, the septic tank on a STEP system must be pumped out every 2 years and the septage disposed of.

(d) The size and soil conditions of the individual lots.

(e) The nature of the waste treatment system and the percentage of total flow to the treatment facility that the pressure system constitutes. Typically, the per capita flow in any pressure sewer system is substantially lower than those in a gravity sewer system. Accordingly, sewage strengths are higher. Studies undertaken on GP systems have shown that the raw sewage characteristics will be in the following ranges:

Parameter	Concentration (mg/L)	
	Mean	Range
BOD_5	330	216 - 504
COD	310	138 - 1450
TSS	310	133 - 468
TKN	80	41 - 144
Total P	15.9	7.2 - 49.3
Grease	81	31 - 140

It may also occur, on a seasonal basis, that septic conditions develop in a GP system.

In a STEP system the pressure system effluent is septic and the strengths much reduced/changed due to the presence of the septic tank. Studies undertaken (18, 20) suggest that STEP system effluents will have the following typical analysis.

Parameter	Concentration (mg/L)	
	Mean	Range
BOD_5	157	N/A
COD	276	170.5 - 673.5
TSS	36.4	17 - 56.0
TKN	40.9	30.1 - 50.0
Total P	10.4	7.0 - 14.0
Grease	65.0	N/A
Sulphide	1.8	0.06- 5.35

4.6.5.4 Pressure Sewer System Design

General

.01 As has been noted previously, a pressure sewer system is essentially the reverse of a water distribution system. However, it should be noted that a pressure sewer system is constructed like a tree and no looping of pipes should occur.

The purpose of this design approach is to minimize sewage retention time, relay the sewage from the source to the point of disposal via the shortest route and permit/facilitate "automatic" scouring of air/gas accumulations from secondary high points at least once per day.

.02 Typically, pressure sewers range in size from NPS - 1¼ for individual service connections to NPS - 4 or NPS - 6 for "trunk" sewers. These smaller sizes are adequate because of the presence of either a grinder pump (typical 6.35 mm solids size) or an absence of solids as would be the case with a STEP system.

.03 Preliminary to the design of a pressure sewer system, it is essential that a detailed on-site survey of the proposed service area, including the individual lots and homes, be carried out. Items to be determined in this survey include, but are not limited to, the following:

(a) The location of the existing private waste disposal system and the house connection to same relative to the proposed location of the pressure sewer.

(b) Does the existing private system provide basement drainage? How (i.e., gravity or pumped)? Does the homeowner desire basement drainage with the new system?

(c) The location and size of the existing hydro service distribution panel.

(d) The topography and soils condition on the individual lots and in the service area proper.

(e) The homeowners comments re the location of the required pumping unit.

(f) The property limits of each lot.

.04 With the aforementioned information/data, it is then possible to evaluate the type of pressure system to be employed (i.e., GP vs. STEP); the location of the required units (i.e., internal vs. external); the type of unit to be installed (i.e., standard unit; duplex unit; deep bury unit, etc.); the need to upgrade the hydro service etc.

.05 Fundamental concepts that must be accepted/ understood for the successful design and operation of any pressure sewer system include:

(a) sewer sizes are substantially reduced (i.e. NPS-1½ to NPS-4 typically) in order to minimize retention time and to facilitate maintenance of scouring velocities;

(b) sewage flows are substantially lower (180 L/cap.d to 270 L/cap.d no infiltration);

(c) design flows are not based upon a per capita contribution rate but rather on a per pumping unit minimum discharge rate (i.e., 0.69 L/s to 1.0 L/s depending on type of pump); the number of units connected to the line in question and the maximum number of units operating simultaneously (probability) (see Appendix R);

(d) the desirability of having minimum velocities above 0.6 m/s with minimum number of pumps running but the TDH less than the design head of the pump under maximum flow/units operating conditions (see Appendix R);

(e) the need to have the system under a constant positive pressure, where possible, in order to eliminate the probability of syphoning of individual pump units and/or air binding of the sewers proper. When this condition cannot be met naturally through system layout and/or topography, an artificial means such as a counter-weighed check valve in the "offending" line(s) should be provided.

System Layout

.01 A pressure sewer system should be laid out such as to minimize the length of pipe while at the same time having no loops. Pipe sizes at the extremities of the system will be the smallest and become progressively larger as dictated by system hydraulics/head losses.

.02 In areas where adverse climatological and/or soils conditions exist, a shallow buried thermally insulated piping system with an active heat tracing system if necessary should be used. The material of construction in such an instance should be a package pipe similar to that described in Section 4.5.4.

Design Considerations for Individual Pumping Units

.01 Serviceability of the on-lot components in either the GP or the STEP system is important in order to minimize the down time due to malfunction and to keep the cost of inspection and maintenance at a minimum. Quick disconnect features are recommended for the piping and electrical connections in order that operations personnel can quickly remove and replace the unit. It is also recommended that in the case of STEP systems employing submersible pumping units, nonmetallic (i.e., thermoplastic) materials be utilized for any piping within the septic tank proper due to the corrosive atmosphere within the tank.

.02 Each building/dwelling to be serviced should be provided with its own unit. Sharing units is not recommended due to the potential this creates for disputes when malfunctions occur. However, locating of adjacent lot service connections in a common trench should be considered if the appropriate easement agreements can be obtained.

.03 Non-domestic services such as motels, restaurants, service centres, etc. should generally be equipped with a duplex pumping unit.

.04 Services to restaurants, service stations, etc. should be equipped with an approved grease/gasoline trap in advance of the unit.

Pressure Sewer Appurtenances

.01 The number and type of appurtenances to be provided on any individual pressure sewer system is a matter of some discussion and no hard rule appears to be available. As a general guide, however, it is recommended that the following be provided:

(a) Each service connection should be equipped with a redundant check valve (i.e., a second check valve in addition to the integral unit within the pump discharge piping) to prevent any backflow. A ball type curb stop should also be provided at the property line of each service connection.

(b) Each branch line should be equipped with an isolation valve.

(c) The end of each branch line should be equipped with a connection to facilitate flushing and/or scouring of the line with water or compressed air. (Figure 4-21.)

(d) Mainline pressure sewers should be equipped with isolation valves at a maximum of 200 m spacing and each line valve chamber should be equipped with bypass pipes/blow-offs and valves as shown in Figure 4-22.

(e) Where precast manhole sections are utilized for chambers, they should be strapped in accordance with the Ministry's Research Report No. 78 entitled "Prevention of Frost Heave in Manholes". This is described in Appendix 'P'.

(f) All chambers and the piping within same should be adequately protected against frost action and insulated and heat traced, as necessary, in order to reduce the potential for freezing at the chambers, which constitute a local point of high heat loss. In addition, all chambers should be equipped with a small sump pump to remove any accumulated surface drainage.

(g) If it is decided to construct a shallow buried, thermally insulated pressure sewer system without heat tracing, an external thaw tube; provision to permit draining of the system or compressed air blow-outs should be provided. The system drains and compressed air blow-out connections should be provided in a chamber at all the low points in the system.

(h) Double-acting air relief valves and syphon breakers should be provided in a chamber at all significant high points in the system.

(i) Spare pumping units (say 5% of total installed) should be purchased as spares.

Construction/Operation Recommendations

(i) Construction

01 Past experience has indicated that the pumping units should be installed as soon as possible after they are delivered to the site. In addition, the unit should be tested prior to installation to ensure it is in operational condition.

.02 Careful supervision of the installation of system components such as the pumping units, the heat tracing cables, etc. should be ensured.

.03 Ensure that proper contraction/expansion allowances are provided in the system (snaking of the pipes, sand bagging of long radius bends, etc.).

.04 Although not possible in every situation, it is recommended practice to install an electrically heat-traced service right up to the building in order to ensure electrical continuity and not stop at the property line.

.05 All pressure sewer lines should be pressure tested to the same specifications as that of a watermain.

.06 Close supervision is required to ensure that all valve chambers are watertight, and a sump should be provided.

.07 The final plumbing and electrical connections between the unit and the home is generally considered to be the responsibility of the homeowner. For overall system security, it is essential that such connections be made by qualified personnel. Ministry experience has shown that the inclusion of these final connections, as a provisional item, in the general contract, with the cost paid by homeowners, is the preferred approach. This method has the advantage of giving the homeowner a fair price while at the same time protecting the interests of both the operating authority and the contractor insofar as faulty installations are concerned.

.08 The question often arises as to the potential/probability of over filling the pump wet well during prolonged unit outages due to power failures. Generally, this would only occur when the building receives its water from a communal water supply which is equipped with standby power and/or an elevated water storage tank. In such circumstances the municipality and/or the homeowner may wish to consider the installation of an electrically operated solenoid shut-off valve on water service connection. This valve would be wired in the "normally open" position and coupled either to the high water alarm in the pump unit or directly to the house power.

.09 Each pressure sewer system installation should include the preparation and distribution of a Homeowner's Manual which outlines the concept of a pressure system; details the specific equipment installed in the project; outlines the division of responsibilities and the use and care of the units and what to do in an emergency. In addition, this manual should include the manufacturer's warranty; a copy of the easement access agreement should one exist; and a pump service/maintenance record sheet.

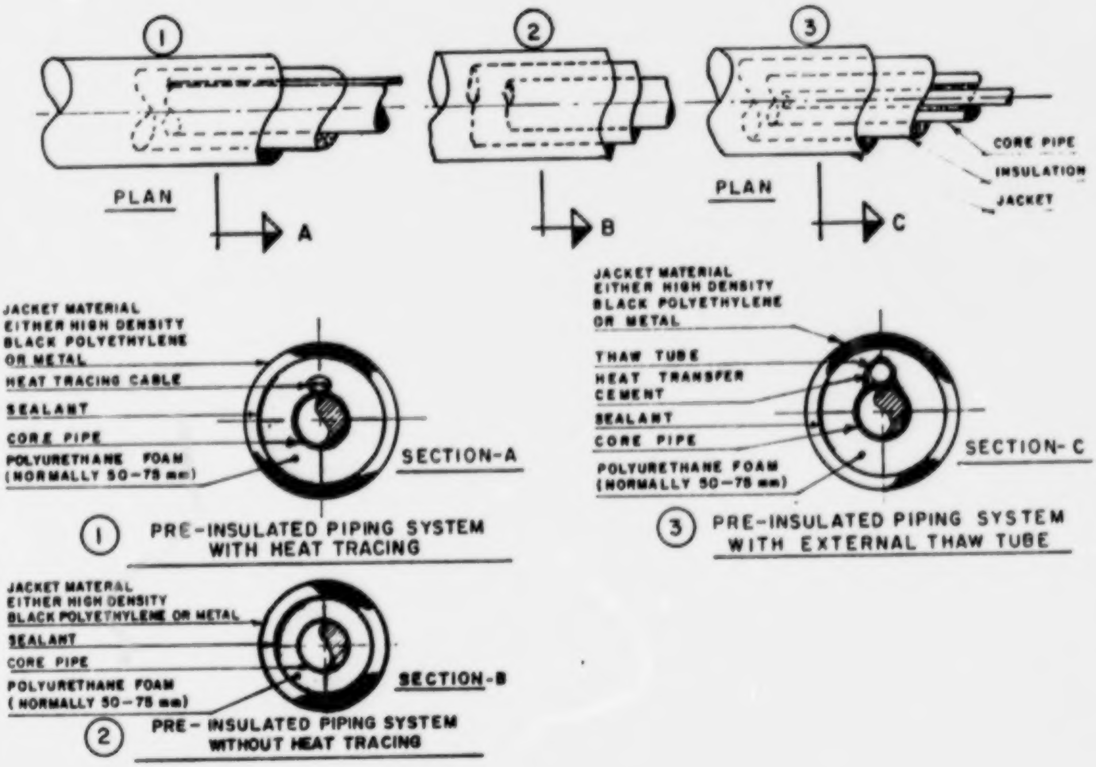
4.6.6 Cluster Pumping Stations

.01 A cluster type system employs certain of the principles of both a gravity sewer system and a pressure sewer system.

.02 With this system a "cluster" of homes is serviced via a common gravity sewer to a small sewage pumping station which is equipped with centrifugal grinder pumps. The individual pumping stations discharge via a common forcemain/pressure sewer system to the ultimate point of discharge, be it a gravity sewer or a waste treatment facility.

.03 This approach minimizes the depth of the gravity sewers and forcemains and facilitates the economic servicing of remote clusters of homes which are "satellite" to a larger system.

.04 To date experience with this approach to servicing is relatively limited, however, it has been employed at the Baptist Camp on Marys Lake in Muskoka and in servicing of the Toronto Island residential community.


①
②
③
PLAN
PLAN
A
B
C
CORE PIPE
INSULATION
JACKET
JACKET MATERIAL EITHER HIGH DENSITY BLACK POLYETHYLENE OR METAL
HEAT TRACING CABLE
SEALANT
CORE PIPE
POLYURETHANE FOAM (NORMALLY 50-75 mm)
SECTION-A
JACKET MATERIAL EITHER HIGH DENSITY BLACK POLYETHYLENE OR METAL
THAW TUBE
HEAT TRANSFER CEMENT
SEALANT
CORE PIPE
POLYURETHANE FOAM (NORMALLY 50-75 mm)
SECTION-C
JACKET MATERAL EITHER HIGH DENSITY BLACK POLYETHYLENE OR METAL
SEALANT
CORE PIPE
POLYURETHANE FOAM (NORMALLY 50-75 mm)
SECTION-B

① PRE-INSULATED PIPING SYSTEM WITH HEAT TRACING

③ PRE-INSULATED PIPING SYSTEM WITH EXTERNAL THAW TUBE

② PRE-INSULATED PIPING SYSTEM WITHOUT HEAT TRACING

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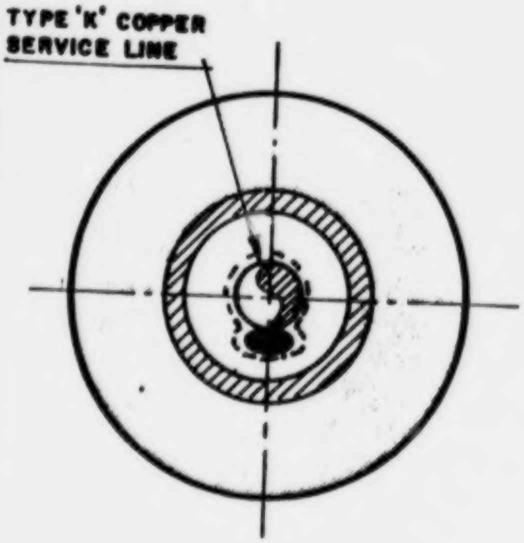
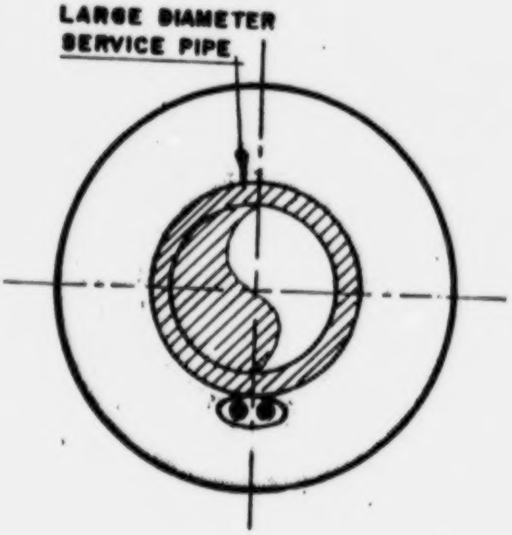
FACTORY FABRICATED PRE-INSULATED WATER PIPING SYSTEM TYPES

FIG. 4-1

DATE: APRIL 1984


TYPE 'K' COPPER
SERVICE LINE

DUCT PIPE WITH SINGLE SERVICE LINE


LARGE DIAMETER
SERVICE PIPE

INDIVIDUALLY INSULATED SERVICE LINE (FOR LARGE DIAMETER SERVICES)

NOTE

ALL MATERIAL SHOWN IS TYPICAL EXCEPT WHERE NOTED

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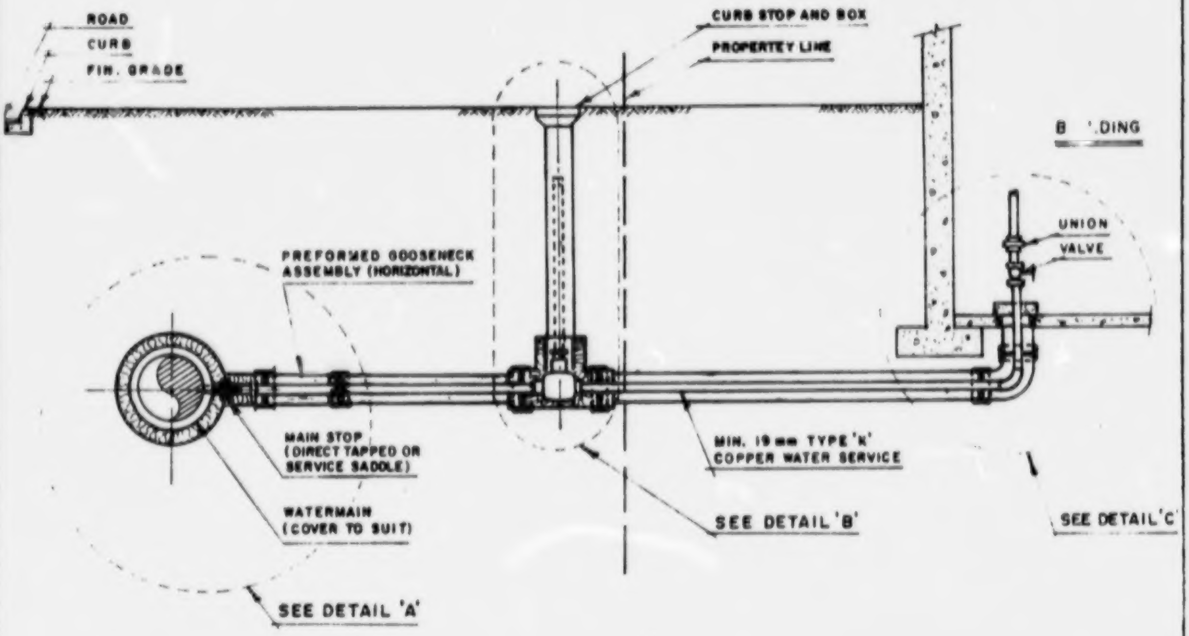
FACTORY FABRICATED PRE-INSULATED WATER SERVICE LINE TYPES

FIG. 4-2

DATE: APRIL 1984


ROAD
CURB
FIN. GRADE
CURB STOP AND BOX
PROPERTEY LINE
B '.DING
UNION
VALVE
PREFORMED GOOSENECK ASSEMBLY (HORIZONTAL)
MAIN STOP (DIRECT TAPPED OR SERVICE SADDLE)
WATERMAIN (COVER TO SUIT)
MIN. 19 mm TYPE 'K' COPPER WATER SERVICE
SEE DETAIL 'B'
SEE DETAIL 'C'
SEE DETAIL 'A'

NOTE

HEAT TRACING MAY BE REQUIRED
FOR SERVICE CONNECTION

NOTE

HEAT TRACING WILL GENERALLY
BE REQUIRED

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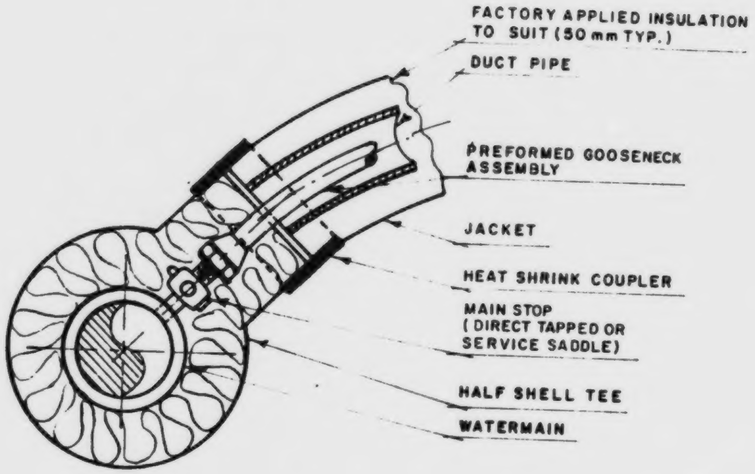
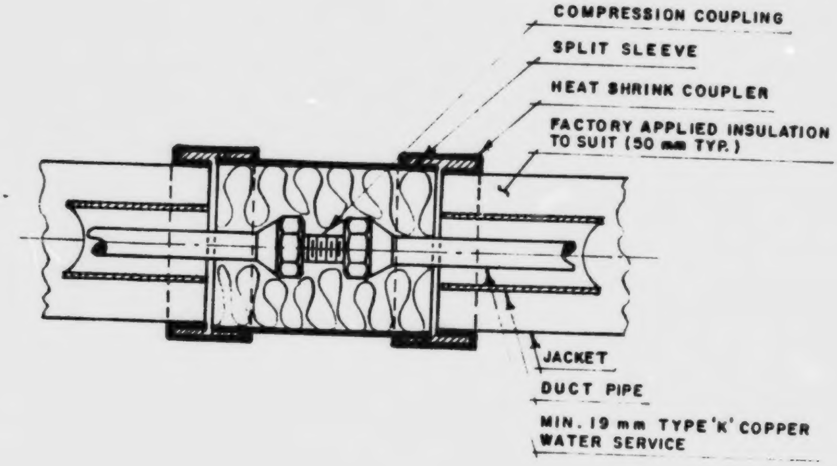
TYPICAL INSULATED WATER
SERVICE CONNECTION

FIG. 4-3		DATE: APRIL 1984


FACTORY APPLIED INSULATION TO SUIT (50 mm TYP.)
DUCT PIPE
PREFORMED GOOSENECK ASSEMBLY
JACKET
HEAT SHRINK COUPLER
MAIN STOP (DIRECT TAPPED OR SERVICE SADDLE)
HALF SHELL TEE
WATERMAIN


COMPRESSION COUPLING
SPLIT SLEEVE
HEAT SHRINK COUPLER
FACTORY APPLIED INSULATION TO SUIT (50 mm TYP.)
JACKET
DUCT PIPE
MIN. 19 mm TYPE 'K' COPPER WATER SERVICE

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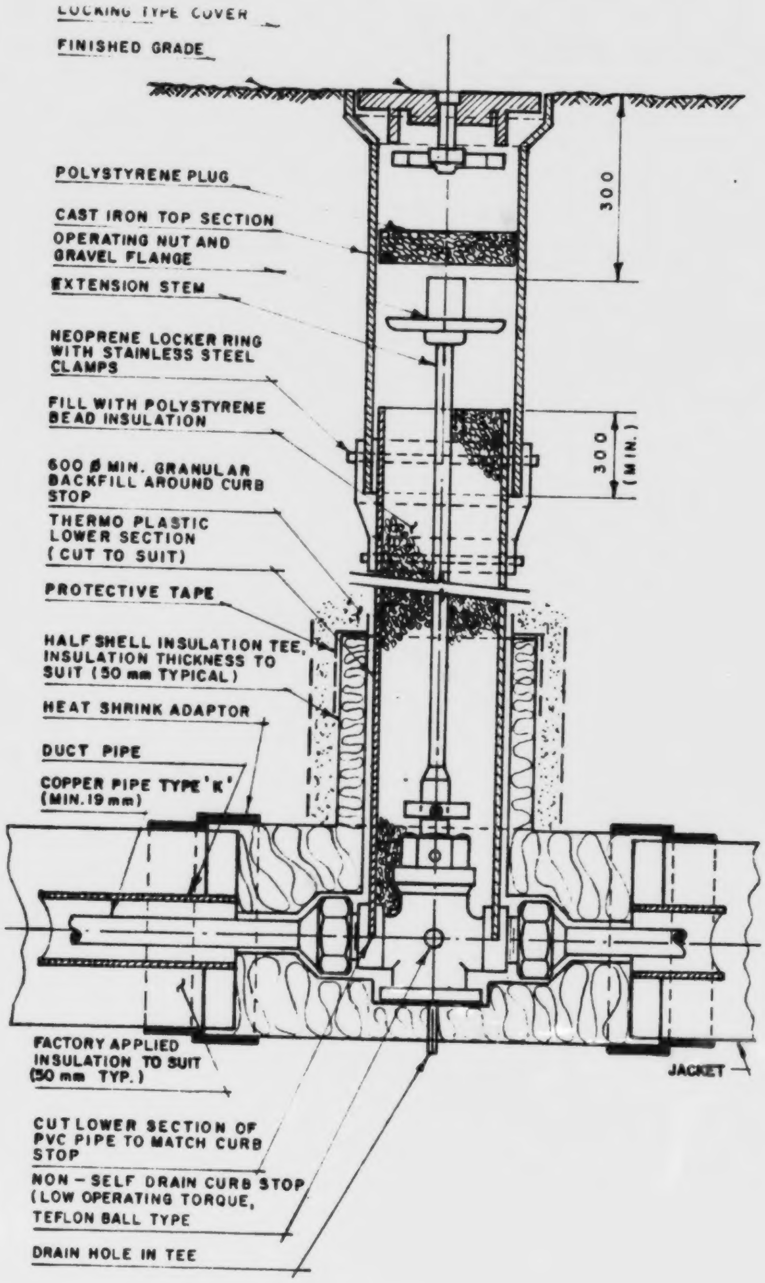
TYPICAL INSULATED WATER
SERVICE CONNECTION
DETAIL 'A'

FIG. 4-4		DATE: APRIL 1984


LOCKING TYPE COVER
FINISHED GRADE
POLYSTYRENE PLUG
CAST IRON TOP SECTION
OPERATING NUT AND GRAVEL FLANGE
EXTENSION STEM
NEOPRENE LOCKER RING WITH STAINLESS STEEL CLAMPS
FILL WITH POLYSTYRENE BEAD INSULATION
600 Ø MIN. GRANULAR BACKFILL AROUND CURB STOP
THERMO PLASTIC LOWER SECTION (CUT TO SUIT)
PROTECTIVE TAPE
HALF SHELL INSULATION TEE, INSULATION THICKNESS TO SUIT (50 mm TYPICAL)
HEAT SHRINK ADAPTOR
DUCT PIPE
COPPER PIPE TYPE 'K' (MIN. 19 mm)
FACTORY APPLIED INSULATION TO SUIT (50 mm TYP.)
CUT LOWER SECTION OF PVC PIPE TO MATCH CURB STOP
NON-SELF DRAIN CURB STOP (LOW OPERATING TORQUE, TEFLON BALL TYPE
DRAIN HOLE IN TEE
JACKET
300
300 (MIN.)

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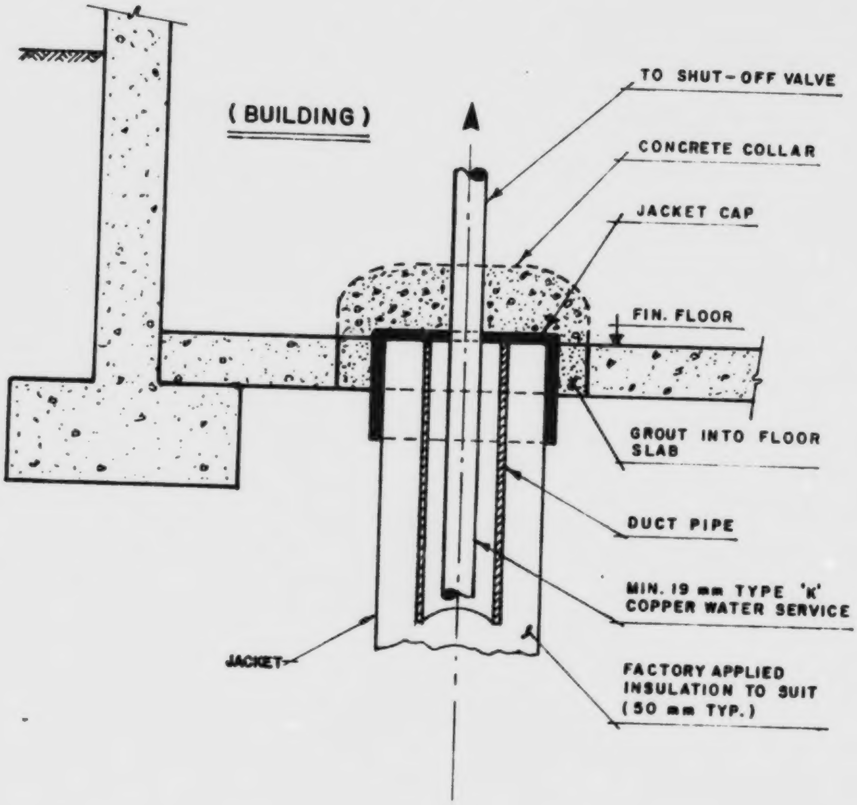
MINISTRY OF THE ENVIRONMENT

TYPICAL INSULATED WATER SERVICE CONNECTION DETAIL 'B'

FIG. 4-5

DATE: APRIL 1984


(BUILDING)
TO SHUT-OFF VALVE
CONCRETE COLLAR
JACKET CAP
FIN. FLOOR
GROUT INTO FLOOR SLAB
DUCT PIPE
MIN. 19 mm TYPE 'K' COPPER WATER SERVICE
FACTORY APPLIED INSULATION TO SUIT (50 mm TYP.)
JACKET

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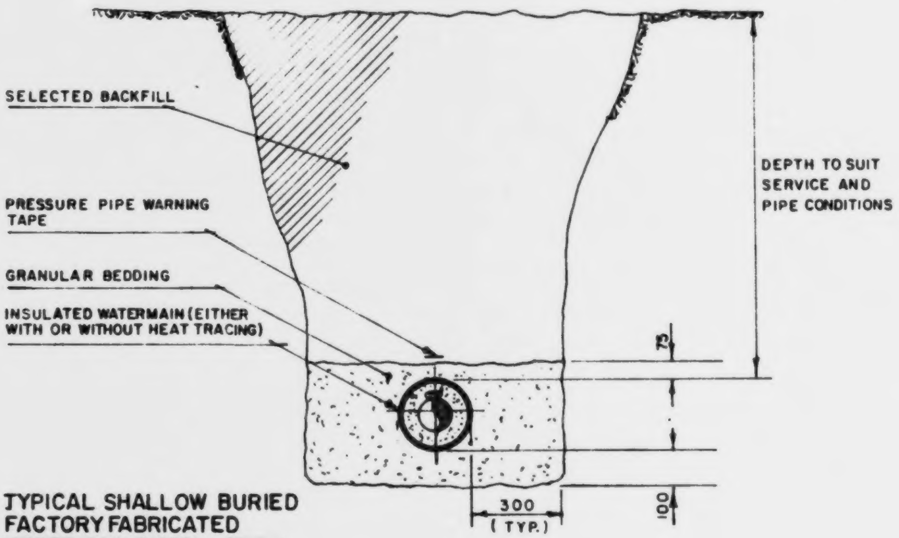
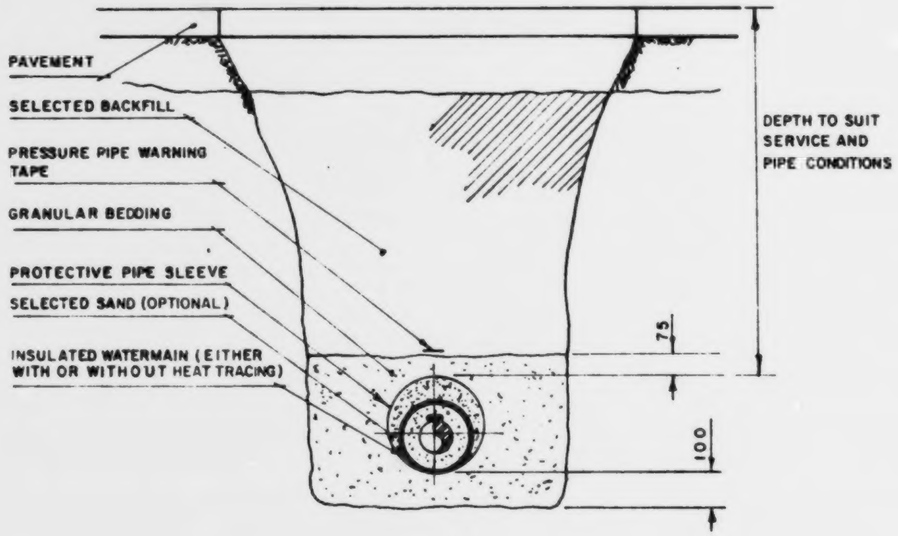
TYPICAL INSULATED WATER
SERVICE CONNECTION
DETAIL 'C'

FIG. 4-6

DATE: APRIL 1984


SELECTED BACKFILL
PRESSURE PIPE WARNING TAPE
GRANULAR BEDDING
INSULATED WATERMAIN (EITHER WITH OR WITHOUT HEAT TRACING)
DEPTH TO SUIT SERVICE AND PIPE CONDITIONS
75
300
(TYP.)
100

TYPICAL SHALLOW BURIED FACTORY FABRICATED WATERMAIN INSTALLATION


PAVEMENT
SELECTED BACKFILL
PRESSURE PIPE WARNING TAPE
GRANULAR BEDDING
PROTECTIVE PIPE SLEEVE
SELECTED SAND (OPTIONAL)
INSULATED WATERMAIN (EITHER WITH OR WITHOUT HEAT TRACING)
DEPTH TO SUIT SERVICE AND PIPE CONDITIONS
75
100

NOTE

WHERE DEPTH OF BURY IS LESS THAN 1.2 M AND THE PIPE WILL BE SUBJECT TO VEHICULAR LOADING (IE ROAD CROSSINGS, ETC.) THE PIPE SHOULD BE INSTALLED IN A CSP SECTION OR BE METAL CLAD.

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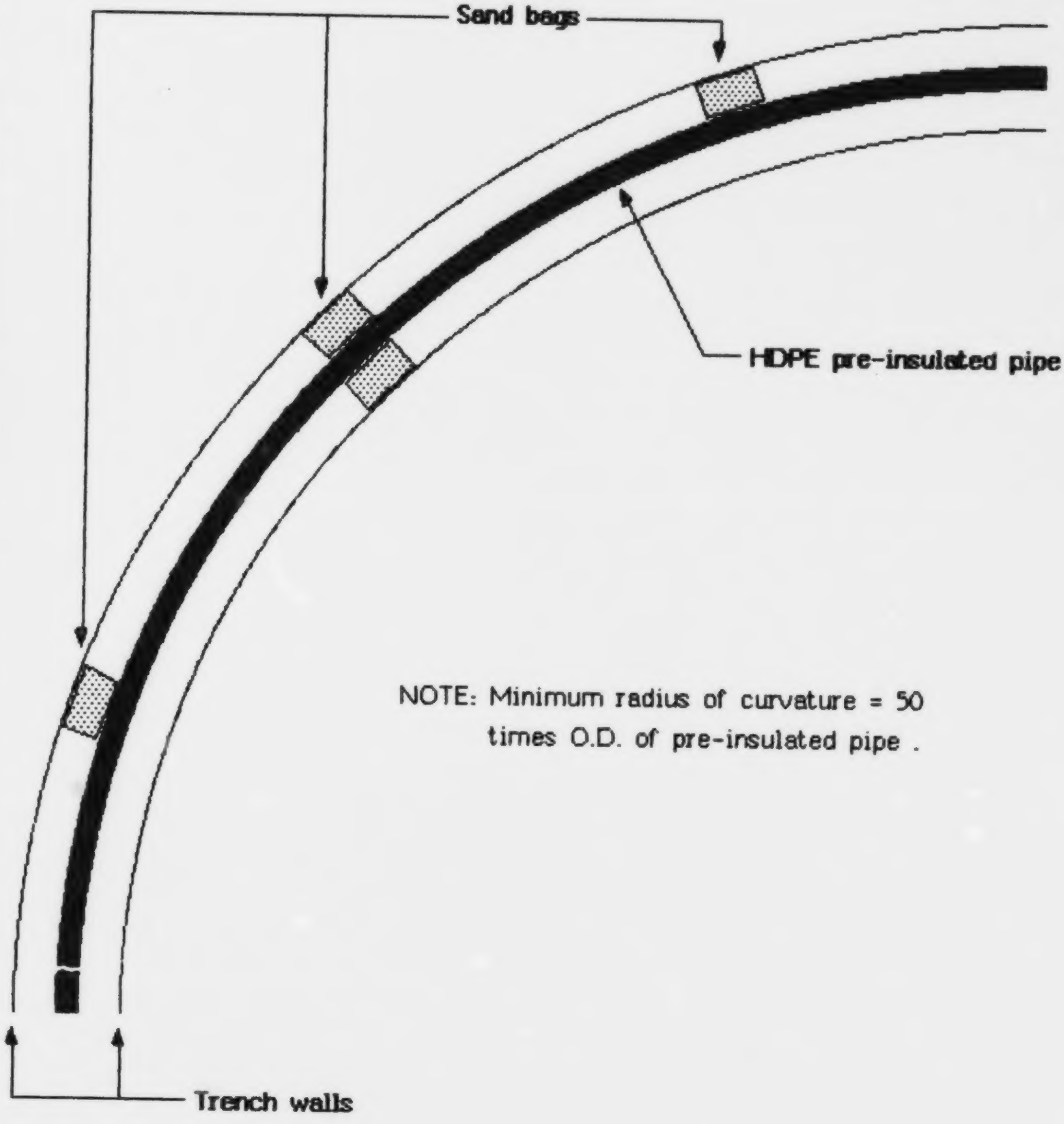
INSTALLATION DETAILS
FACTORY FABRICATED,
PREINSULATED PIPE

FIG. 4-7

DATE: APRIL 1984


Sand bags
HDPE pre-insulated pipe
Trench walls

NOTE: Minimum radius of curvature = 50
times O.D. of pre-insulated pipe .

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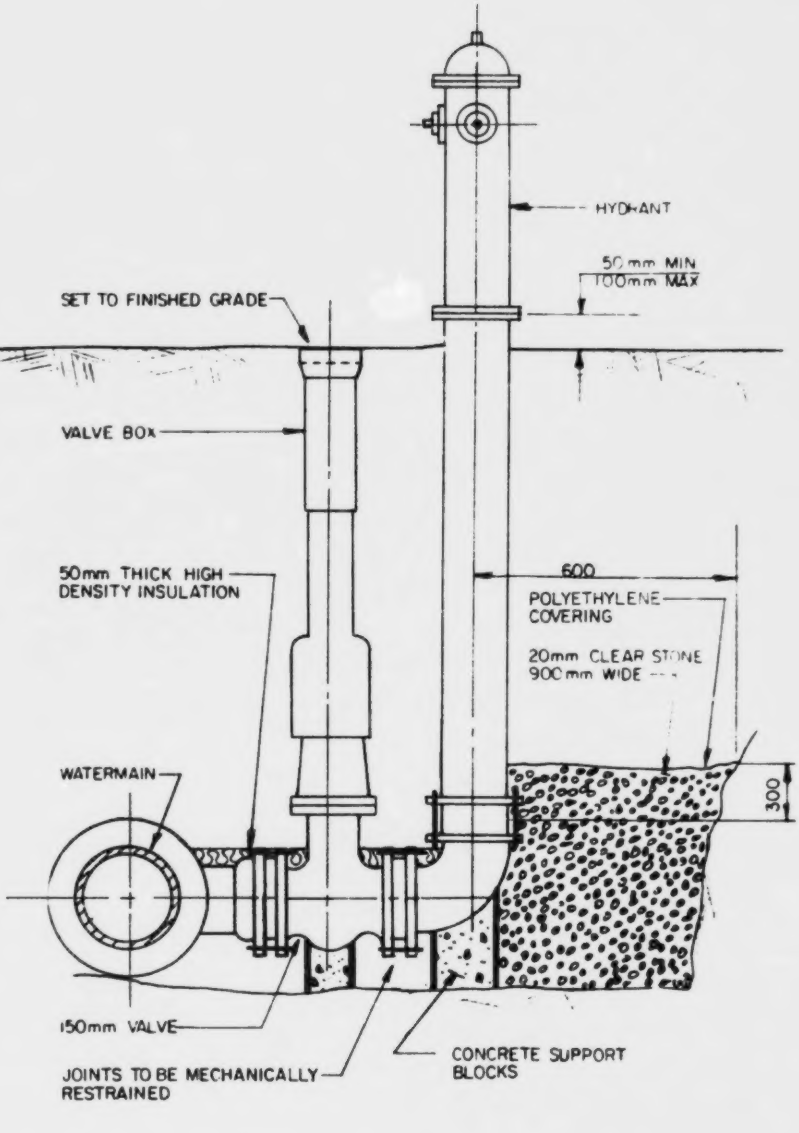
LONG RADIUS CURVE PIPE PROTECTION

FIG. 4-8

DATE: APRIL 1984


HYDRANT
50 mm MIN
100mm MAX
SET TO FINISHED GRADE
VALVE BOX
50mm THICK HIGH DENSITY INSULATION
600
POLYETHYLENE COVERING
20mm CLEAR STONE 900mm WIDE
WATERMAIN
300
150mm VALVE
JOINTS TO BE MECHANICALLY RESTRAINED
CONCRETE SUPPORT BLOCKS

NOTES:

A All concrete to be 20MPa compresive strength.
B All concrete blocking to be poured against undisturbed earth.
C Polyethylene bond breaker to be used between concrete and fittings.
D Bolts and drain rings are to be stainless steel.
E All dimensions are in millimetres unless otherwise shown.

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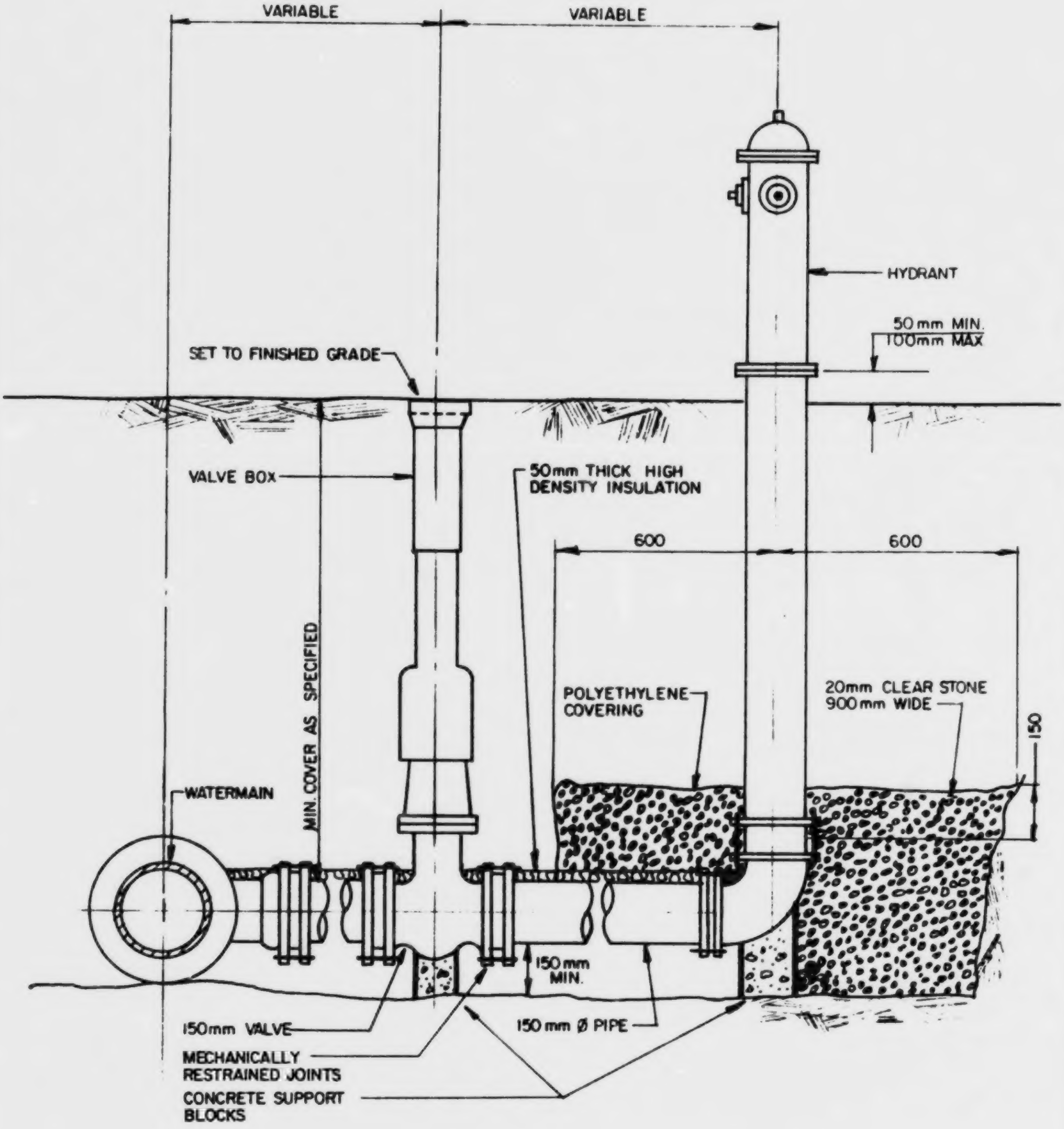
CLOSE-COUPLED
FIRE HYDRANT

FIG. 4-9

DATE: APRIL 1984


VARIABLE
VARIABLE
HYDRANT
50 mm MIN.
100mm MAX
SET TO FINISHED GRADE
VALVE BOX
50mm THICK HIGH DENSITY INSULATION
600
600
MIN. COVER AS SPECIFIED
POLYETHYLENE COVERING
20mm CLEAR STONE 900mm WIDE
150
WATERMAIN
150mm MIN.
150mm VALVE
150 mm Ø PIPE
MECHANICALLY RESTRAINED JOINTS
CONCRETE SUPPORT BLOCKS

NOTES:

A All concrete to be 20MPa compresive strength.

B All concrete blocking to be poured against undisturbed earth.

C Polyethylene bond breaker to be used between concrete and fittings.

D Bolts and drain rings are to be stainless steel.

E All dimensions are in millimetres unless otherwise shown.

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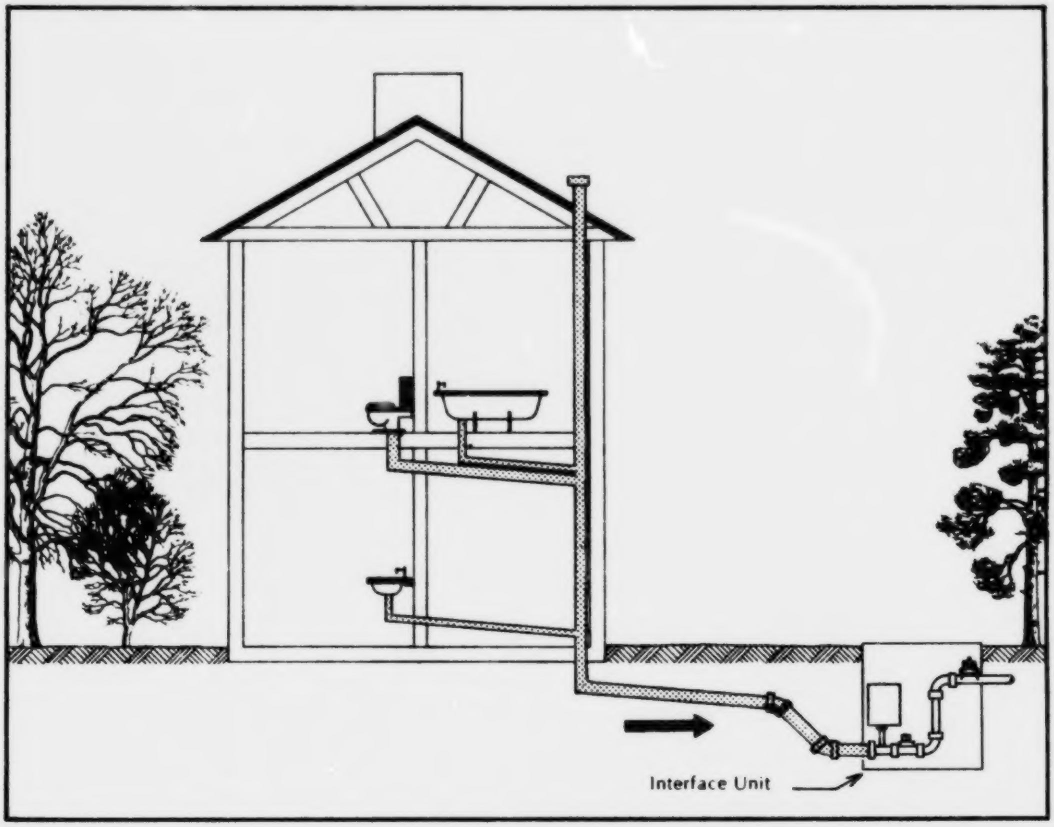
STANDARD FIRE HYDRANT

FIG. 4-10

DATE: APRIL 1984



Courtesy Vacusan,
Division of
Euroclean Canada Inc.

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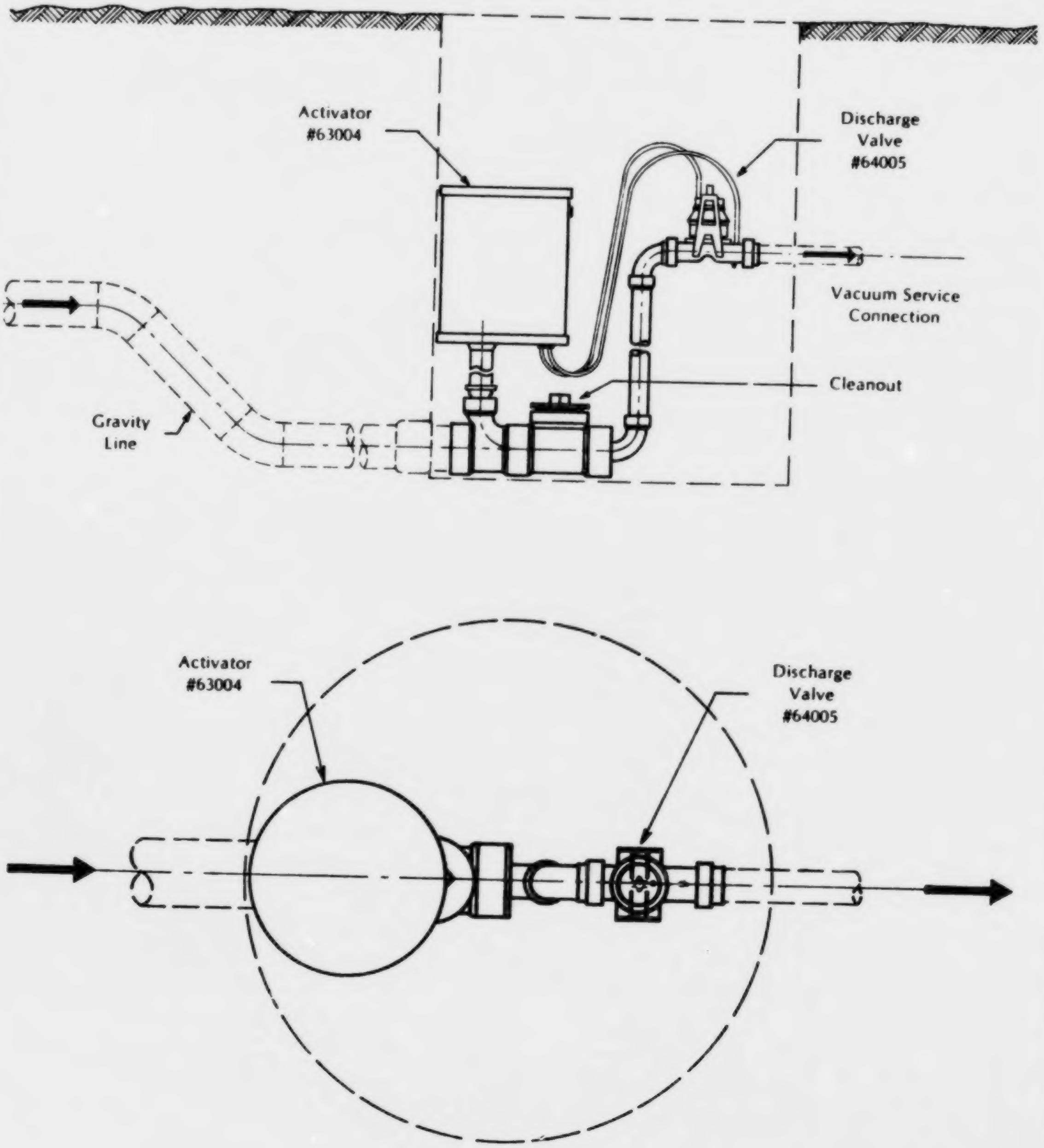
SCHEMATIC OF HOUSE PLUMBING
CONNECTION TO VACUUM INTERFACE UNIT

FIG. 4-11		DATE: APRIL 1984


Activator
#63004
Discharge
Valve
#64005
Vacuum Service
Connection
Cleanout
Gravity
Line
Activator
#63004
Discharge
Valve
#64005

Courtesy Vacusan,
Division of
Euroclean Canada Inc.

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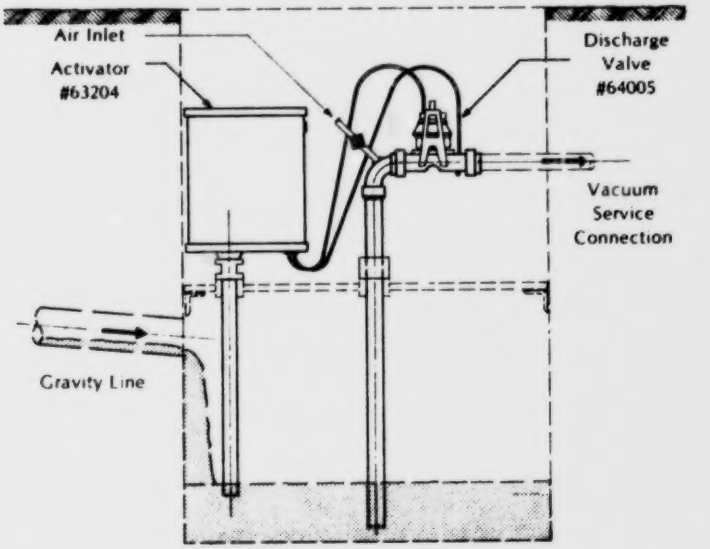
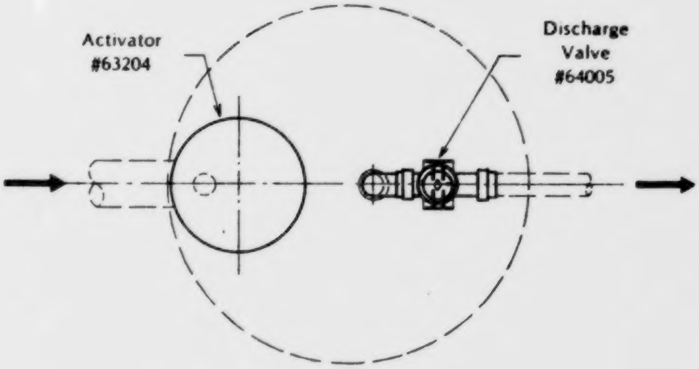
STANDARD TYPE
VACUUM INTERFACE UNIT

FIG. 4-12 (a)

DATE: APRIL 1984


Air Inlet
Activator
#63204
Discharge
Valve
#64005
Vacuum
Service
Connection
Gravity Line


Activator
#63204
Discharge
Valve
#64005

Courtesy Vacusan,
Division of
Euroclean Canada Inc.

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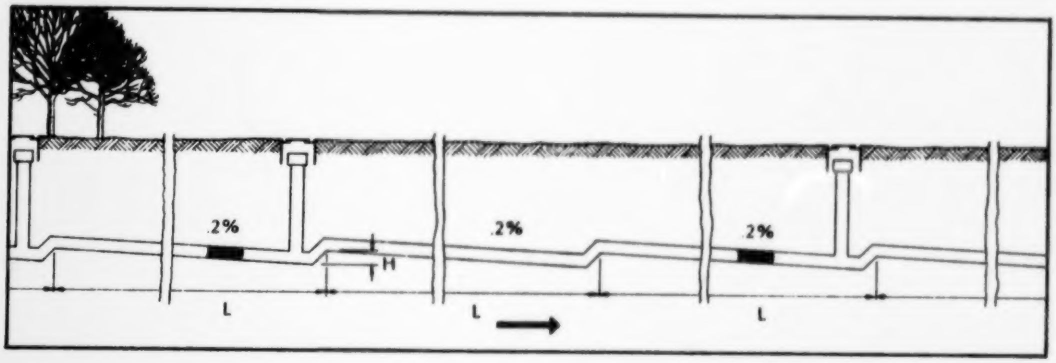
BUFFER TYPE VACUUM
INTERFACE UNIT

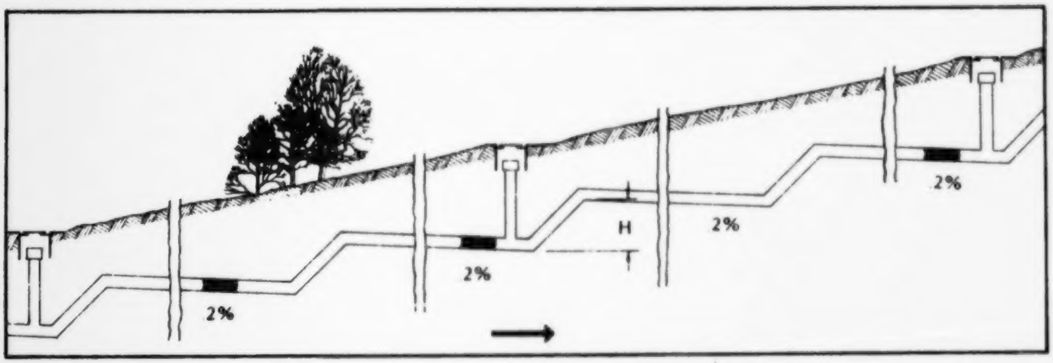
FIG. 4-12 (b)

DATE: APRIL 1984

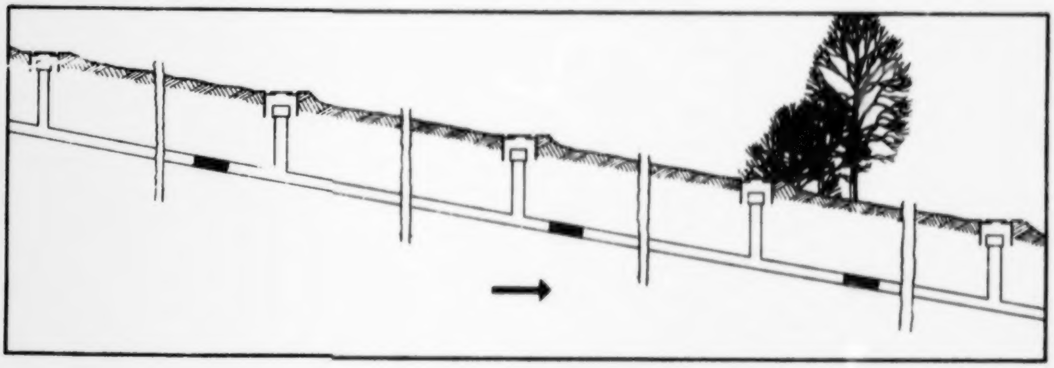
HORIZONTAL TRANSPORT



UPHILL TRANSPORT



DOWNHILL TRANSPORT



Courtesy Vacusan,
Division of
Euroclean Canada Inc.

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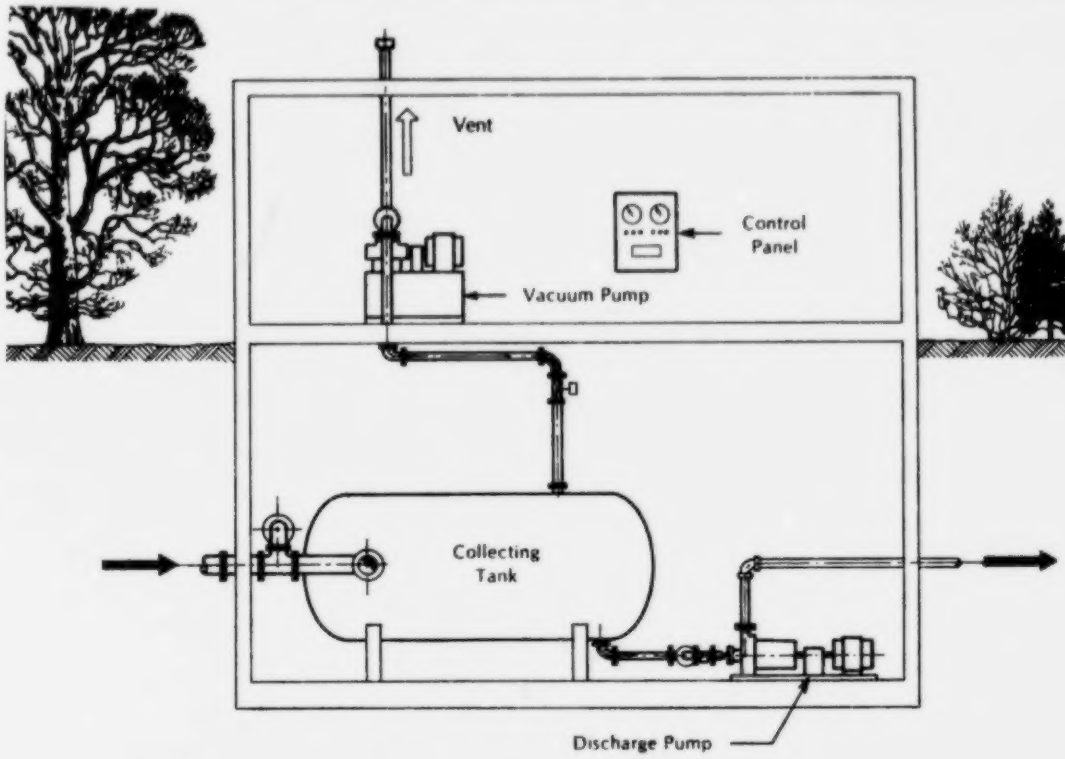
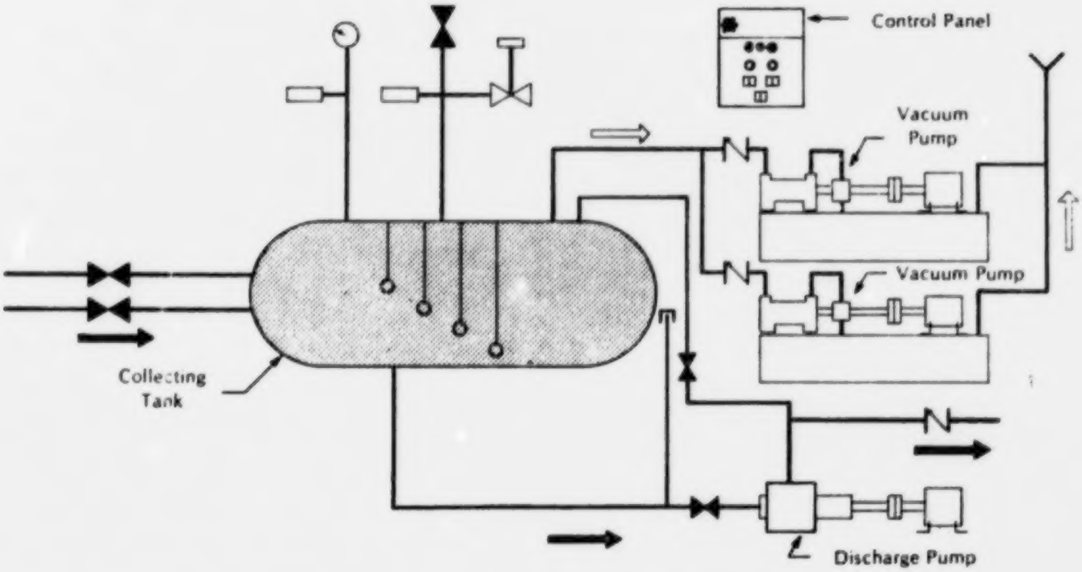
TYPICAL VACUUM SEWER PROFILES

FIG. 4-13

DATE: APRIL 1984


Vent
Control Panel
Vacuum Pump
Collecting Tank
Discharge Pump


Control Panel
Vacuum Pump
Vacuum Pump
Collecting Tank
Discharge Pump

Courtesy Vacusan,
Division of
Euroclean Canada Inc.

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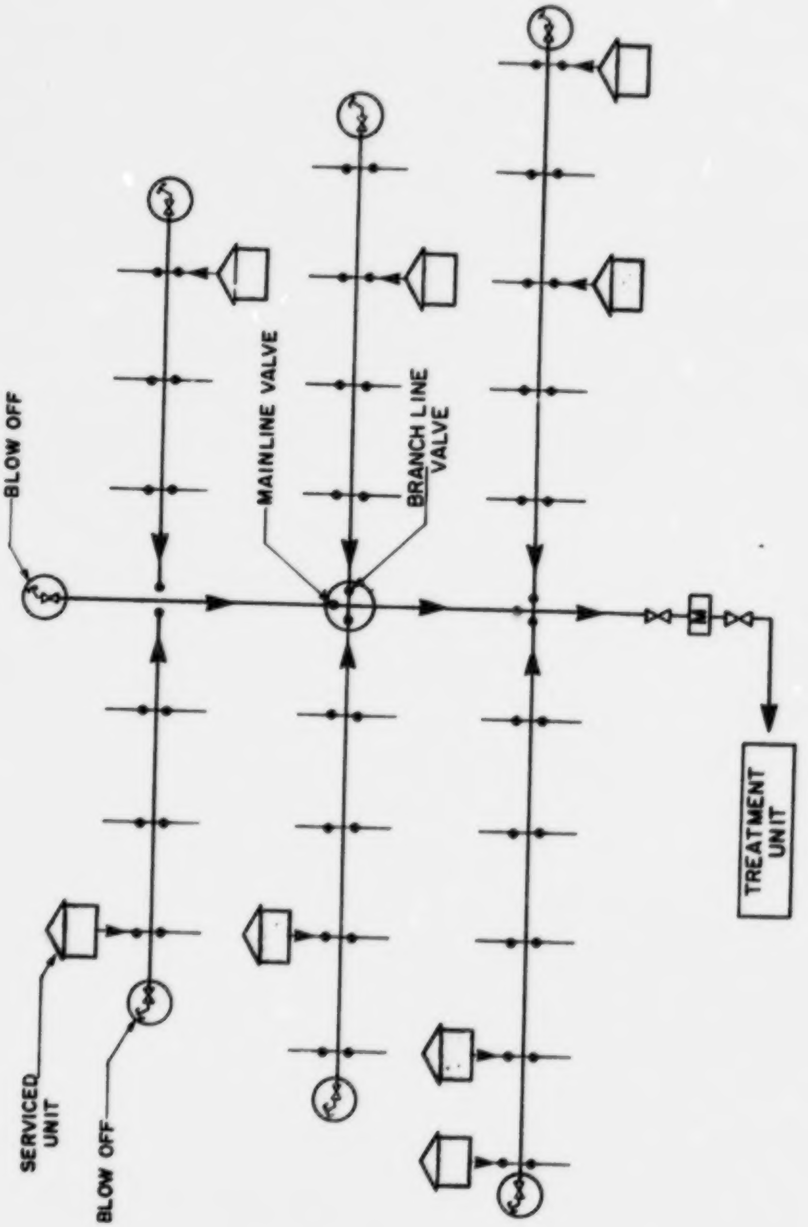
SCHEMATIC OF TYPICAL
VACUUM SEWER COLLECTION STATION

FIG. 4-14

DATE: APRIL 1984


BLOW OFF
MAINLINE VALVE
BRANCH LINE VALVE
M
TREATMENT UNIT
SERVICED UNIT
BLOW OFF

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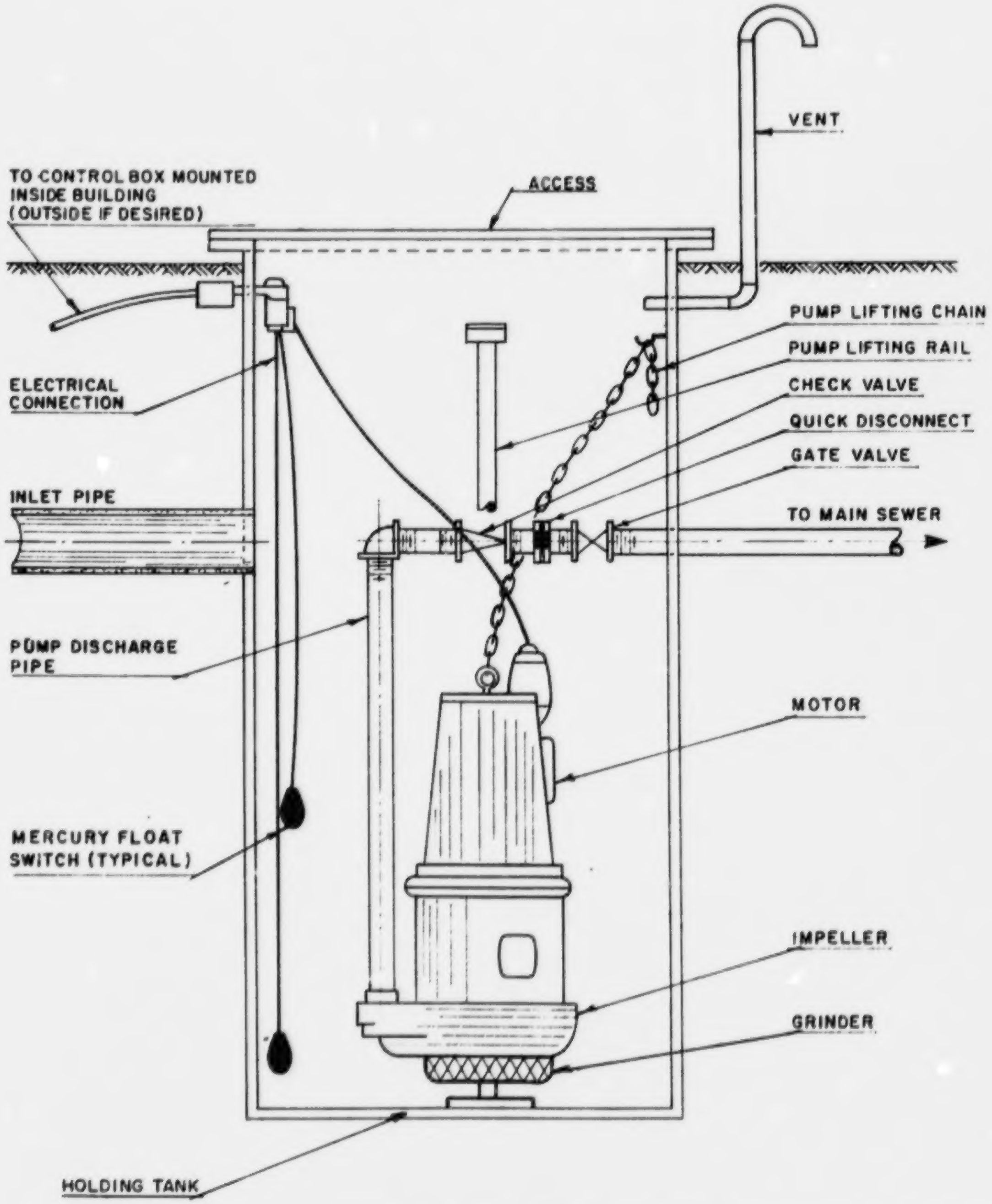
PRESSURE SEWER
DISTRIBUTION SYSTEM

FIG. 4-15

DATE: APRIL 1984


VENT
TO CONTROL BOX MOUNTED INSIDE BUILDING (OUTSIDE IF DESIRED)
ACCESS
PUMP LIFTING CHAIN
PUMP LIFTING RAIL
ELECTRICAL CONNECTION
CHECK VALVE
QUICK DISCONNECT
GATE VALVE
INLET PIPE
TO MAIN SEWER
PUMP DISCHARGE PIPE
MOTOR
MERCURY FLOAT SWITCH (TYPICAL)
IMPELLER
GRINDER
HOLDING TANK

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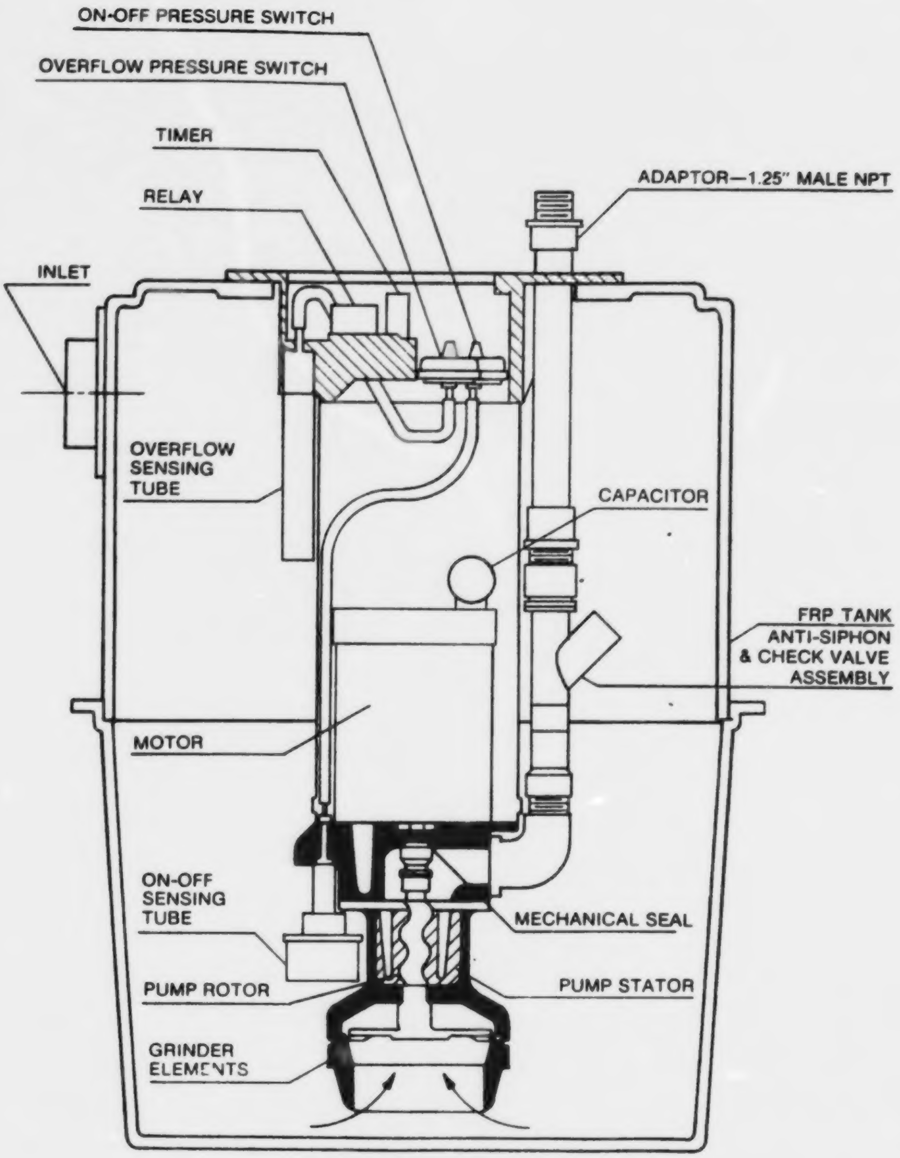
TYPICAL CENTRIFUGAL
GRINDER PUMP

FIG. 4-16

DATE: APRIL 1984


ON-OFF PRESSURE SWITCH
OVERFLOW PRESSURE SWITCH
TIMER
RELAY
ADAPTOR—1.25" MALE NPT
INLET
OVERFLOW SENSING TUBE
CAPACITOR
FRP TANK
ANTI-SIPHON & CHECK VALVE ASSEMBLY
MOTOR
ON-OFF SENSING TUBE
MECHANICAL SEAL
PUMP ROTOR
PUMP STATOR
GRINDER ELEMENTS

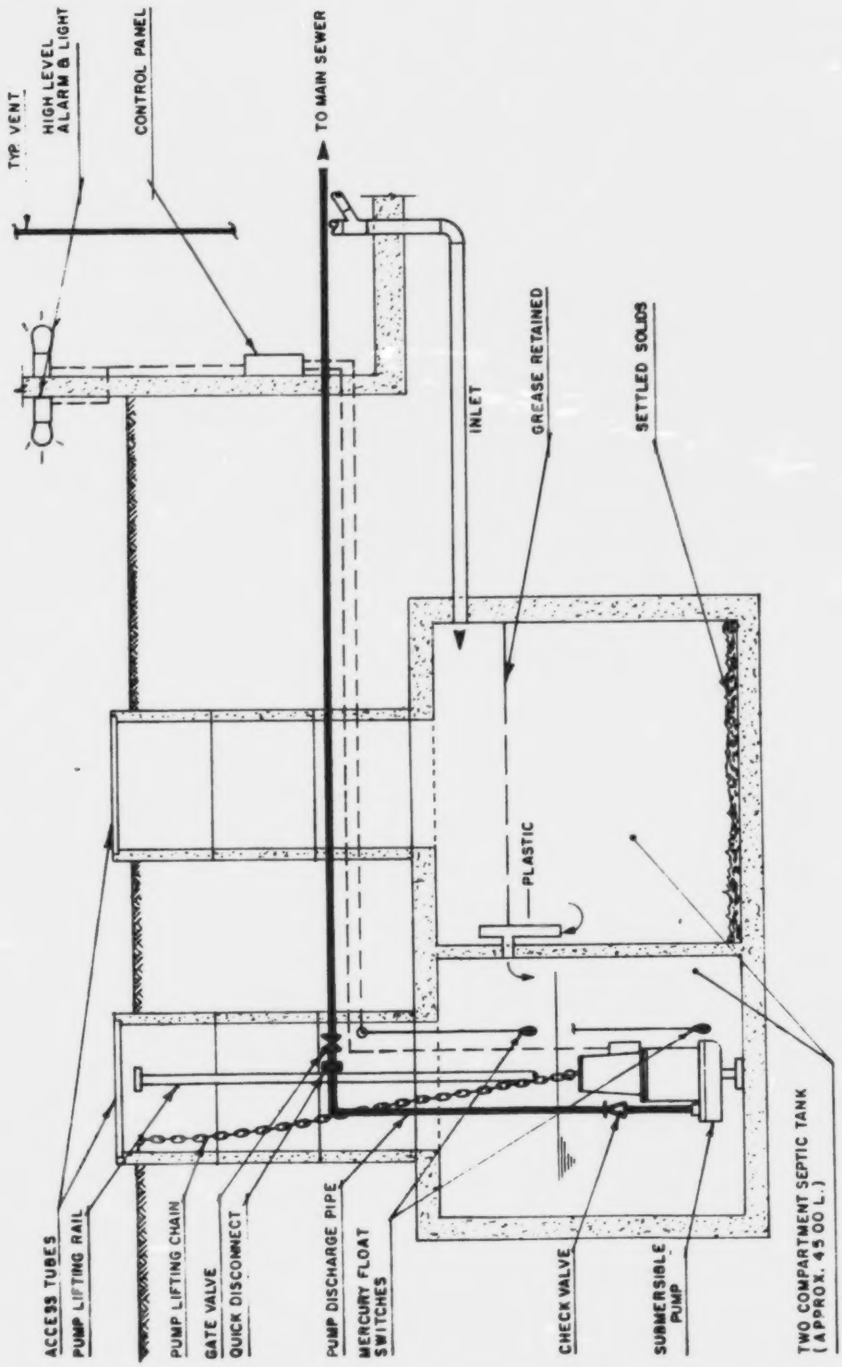
COURTESY OF
ENVIRONMENT
ONE
CORPORATION

ONTARIO
MINISTRY OF THE **ENVIRONMENT**

TYPICAL PROGRESSIVE
CAVITY GRINDER PUMP

FIG. 4—17

DATE: APRIL 1984


TYP. VENT
HIGH LEVEL ALARM & LIGHT
CONTROL PANEL
TO MAIN SEWER
INLET
GREASE RETAINED
SETTLED SOLIDS
PLASTIC
ACCESS TUBES
PUMP LIFTING RAIL
PUMP LIFTING CHAIN
GATE VALVE
QUICK DISCONNECT
PUMP DISCHARGE PIPE
MERCURY FLOAT SWITCHES
CHECK VALVE
SUBMERSIBLE PUMP
TWO COMPARTMENT SEPTIC TANK (APPROX. 4500 L.)

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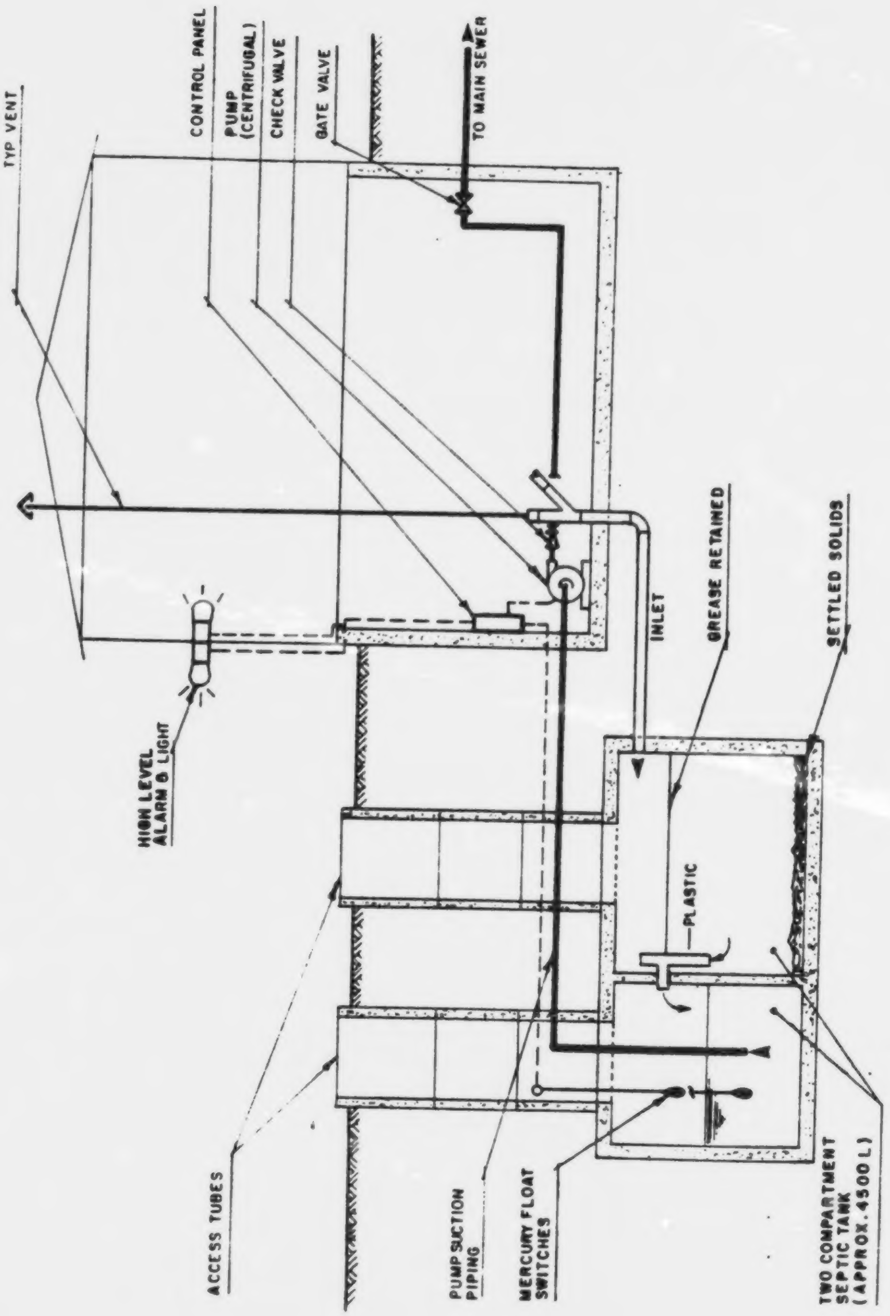
SEPTIC TANK EFFLUENT
PUMPING SYSTEM
(STEP SYSTEM)

FIG. 4-18

DATE: APRIL 1984


TYP VENT
CONTROL PANEL
PUMP (CENTRIFUGAL)
CHECK VALVE
GATE VALVE
TO MAIN SEWER
HIGH LEVEL ALARM & LIGHT
INLET
GREASE RETAINED
SETTLED SOLIDS
PLASTIC
ACCESS TUBES
PUMP SUCTION PIPING
MERCURY FLOAT SWITCHES
TWO COMPARTMENT SEPTIC TANK (APPROX. 4500 L)

ONTARIO
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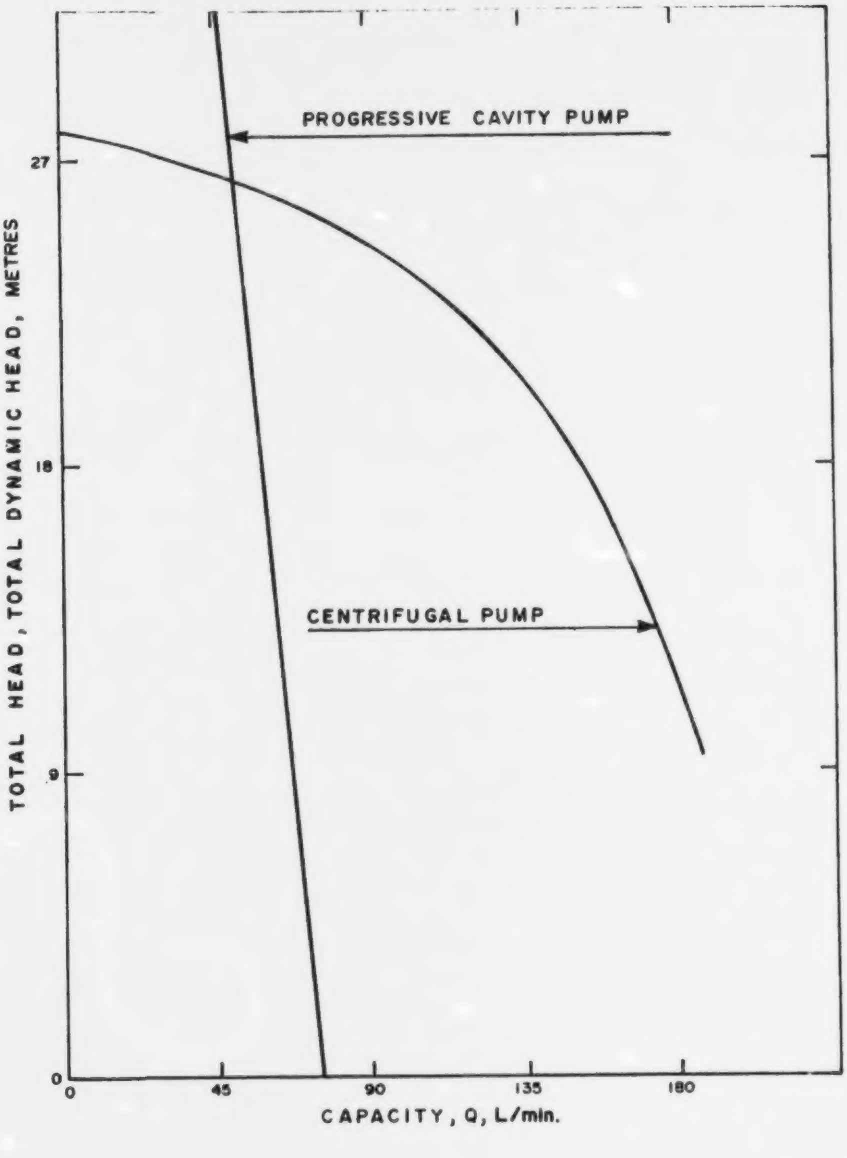
'SASKATCHEWAN' TYPE STEP

FIG. 4-19

DATE: APRIL 1984



ONTARIO
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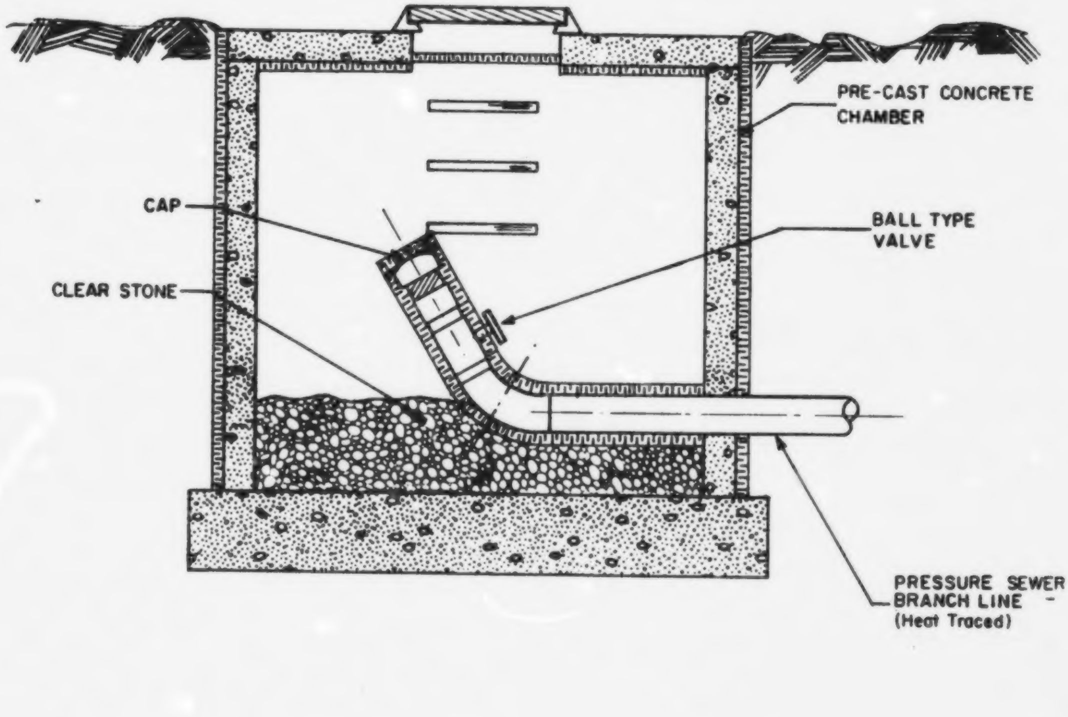
GRINDER PUMP
CHARACTERISTICS

FIG. 4-20

DATE: APRIL 1984


PRE-CAST CONCRETE CHAMBER
CAP
BALL TYPE VALVE
CLEAR STONE
PRESSURE SEWER BRANCH LINE (Heat Traced)

ONTARIO
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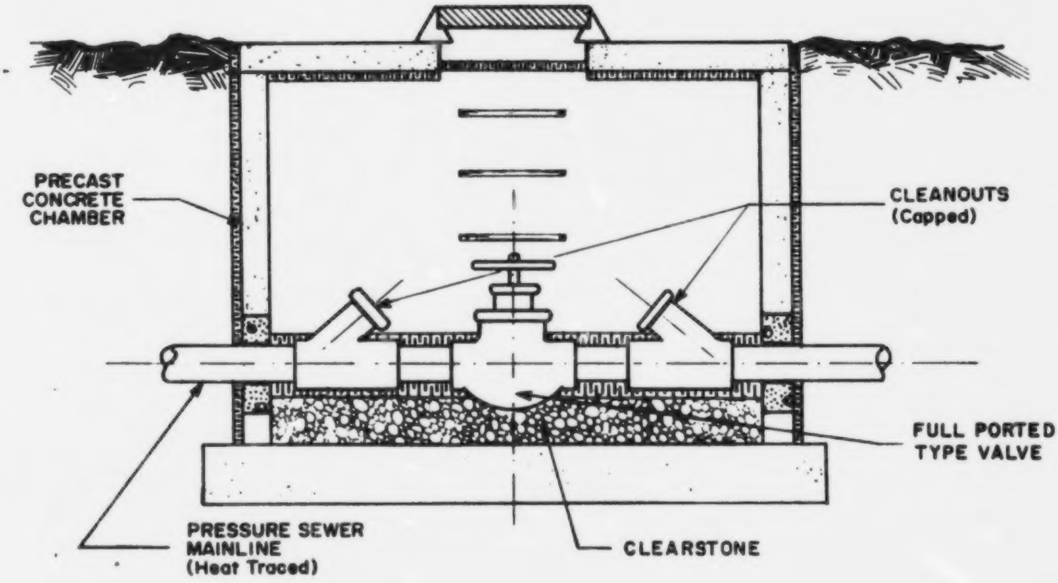
TERMINAL CLEANOUT

FIG. 4-21

DATE: APRIL 1984


PRECAST
CONCRETE
CHAMBER
CLEANOUTS
(Capped)
FULL PORTED
TYPE VALVE
PRESSURE SEWER
MAINLINE
(Heat Traced)
CLEARSTONE

ONTARIO
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TYPICAL VALVE BOX
WITH CLEANOUTS

FIG. 4-22

DATE: APRIL 1984

REFERENCES/BIBLIOGRAPHY

.01 The following bibliography is provided in order to permit the designer to review in detail the alternatives and advances that have been made in the technology associated with water and sanitary seer servicing. While not all of the technologies or the alternatives covered in these references will necessarily be applicable to any given project, it is the firm opinion of the Ministry that these references will provide valuable insight and guidance to the designer of systems that are subject to the effects of difficult or adverse conditions.

.02 As has been indicated in the introduction to these guidelines, it is not intended that these guidelines stifle innovation or that they be considered as standards or regulations which must be absolutely complied with in order to obtain an approval. Rather, the purpose of these guidelines is to suggest that a basic change in the design philosophy is warranted when considering servicing in areas subject to the effect of difficult or adverse conditions.

.03 The majority of papers listed are available for reference through the Ministry's Special Engineering Design nad Equipment Unit, Special Activities Section, Environmental Approvals and Project Engineering Branch.

(1) Environment Canada. "Cold Climate Utilities Delivery Design Manual". Economic and Technical Review Report. Water Pollution Control Directorate. EPS 3-WP-79-2. March 1979.

(2) Environment Canada. "Utilities Delivery in Arctic Regions". Economic and Technical Review Report. Water Pollution Control Directorate. EPS-WP-77-1. January 1977.

(3) Environment Canada. "Utilities Delivery in Northern Regions." Economic and Technical Review Report. Symposium Proceedings. EPS 3-WP-80-5.

(4) Environment Canada. "Utilities Delivery in Cold Regions". Economic and Technical Review Report. Water Pollution Control Directorate. EPS-3-WP-82-6.

(5) "Frost Depth Penetrations - Ontario 1970-74." Research Development Divison, Ontario Ministry of Transporation and Communications.

(6) Cohen, A. "Pipeline Frost Protection Design." Applied Sciences Section. Ontario Ministry of the Environment, 1981.

(7) Cohen, A. "Prevention of Frost Heave in Manholes." Research Report No. 78. Applied Sciences Section. Ontario Ministry of the Environment.

(8) Cohen, Arieh and M.B. Fielding. "Predicting Frost Depth; Protecting Underground Pipelines." Journal AWWA, Feb. 1979.

(9) James, F.W. "Critical Evaluation of Insulated Shallow Buried Pipe Systems, N.W.T., Canada." Department of Public Works Government of N.W.T. June 1979.

(10) Monie, William D. and Curtis M. Clark. "Loads on Underground Pipe due to Frost Penetration." Journal American Water Works Association, Vol. 66, No 6, June 1974.

(11) Smith, W.H. "Evaluation of Frost Loadings on Underground Pipe." Cast Iron Pipe Research Association.

(12) Whyman, P.Eng., A.D. "Pre-insulated Polyethylene Piping - The Evolution of a Northern Achievement." Pipe Division. Dupont Canada. Feb. 1979.

(13) Zarnett, Ph.D., P.Eng., Gerald D. "Design of Buried Pipelines in Cold Climates." Applied Sciences Section. Ontario Ministry of the Environment.

JANUARY 1985

(14) "Temperature Monitoring of an Insulated Watermain." Pollution Control Branch. Ontario Ministry of the Environment.

(15) "Design and Selection of Small Waste Water Treatment Systems." Economic and Technical Review Report. Water Pollution Control Directorate. Environment Canada. EPS 3-WP-80-3, March 1980.

(16) Edel, Professor T.B. & Bahmanyer, G.H. "Stress in Buried Conduits caused by Freezing Front". University of Wisconsin and Milwaukee Testing Divison of Warzyn Engineering Inc.

(17) Edel, T.B. & Bahmanyer, G.H. "Cold Weather Effects on Buried Pipe Failures." University of Wisconsin nad Milwaukee Testing Division of Warzyn Engineering Inc.

(18) "Polyurethane Foam as a Thermal Insulation: A Critical Examination." Division of Building Research, National Research Council of Canada. Building Research Note No. 124.

(19) Eblen, Jessie E. & Lloyd K. Clark. "Pressure and Vacuum Sewer Demonstration Project-Bend, Oregon" C & G Engineering Inc., Salem, Oregon. E.P.A. - 600/2-78-166. September 1978.

(20) Cooper, Ivan A & Joseph W. Rezek. "Experiences with Pressure Sewer Systems". 51st Anual Conference, Water Pollution Control Federation, Anaheim, California. October 1-6, 1978.

(21) Bowne, W.C. "Pressure Sewers." Environmental Research Information Centre, U.S. Environmental Protection Agency. July 1979.

(22) Kreissl, James F., Robert Smith and James A. Heidman. "The Cost of Small Community Waste Water Alternatives". U.S. Environmental Protection Agency. August 1978.

(23) "Alternatives for Small Waste Water Treatment Systems (Pressure Sewers/Vacuum Sewers)". pub. by U..S. Environmental Protection Agency. E.P.A. - 625/4-77-011.

(24) "Alternative for Small Waste Water Treatment Systems (Cost/Effectiveness Analysis)" pub. by U.S. Environmental Protection Agency. E.P.A. - 625/4-77-011.

(25) "Status of Pressure Sewer Technology" by James F. Kreissl for the U.S. Environmental Protection Agency.

(26) "Less Costly Waste Water Treatment Systems for Small Communities" pub. by U.S. Environmental Protection Agency, April 1977.

(27) "A Pressure Sewer System Demonstration" by Italo G. Carich, Leo J. Hepling and R. Paul Farrell for the U.S. Environmental Protection Agency, November 1972.

(28) Gray, Glenn. "Pressure Sewer Systems." Department of Engineering, Univ. of Wisconsin - Extension. June 1979.

(29) Langford, Robert E. "Effluent Pressure System." W.P.C.F. Conference, Philadelphia, Penn. October 1977.

(30) "Design of Pressure Sewer Systems." Published notes from December 1977 University of Wisconsin - Extension Professional Development Program.

(31) "Pressure Sewer Systems." Published notes from November 1979 University of Wisconsin - Extension Professional Development Program.

(32) Flanigan, L.J. and C.A Cadmik. "Pressure Sewer System Design." Published in Water and Sewage Works, Ref. No. 1979.

(33) Lessak, E. "Low Pressure Sewage Systems." Saskatchewan Department of Agriculture/Family Farm Improvement Branch.

(34) Farrell, Jr., R. Paul. "Pressure Sewers and The Grinder Pump Which Makes Them Possible."

(35) "Report on the Performance of Grinder Pump Model Farrell 210." Report No. C-9-3, September 1973. National Sanitation Foundation Testing Laboratory.

(36) "Rose Blanche Newfoundland Water and Sewer System - Operation and Maintenance Report No. 3 (Final)" A Report to Province of Newfoundland and Labrador, Department of Regional Economic Expansion. MacLaren Engineers, Planners and Scientists Inc. July 1981.

(37) "Temagami Pressure Sewer System." Prepared for the Technical Research Division, Policy Development and Research Sector of Canada Mortgage and Housing Corporation, by MacLaren Engineers, Planners and Scientists Inc., October 1982.

(38) "Design Handbook for Low Pressure Sewer System - Third Edition". Environment One Corporation, Schenectady, New York.

GUIDELINES FOR THE DESIGN OF WATER SUPPLY SYSTEMS FOR SMALL RESIDENTIAL DEVELOPMENTS

MARCH 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

The Honourable
Jim Bradley
Minister

Allan E. Dyer,
Deputy Minister

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FORWARD

The initial version of these guidelines was prepared by a committee of Provincial and Municipal Engineers who were familiar with current practice within the Province of Ontario with respect to small residential groundwater supply systems and was entitled, "Recommended Guidelines for Small Groundwater Supply Systems for Residential Developments".

Staff of the Environmental Approvals and Project Engineering Branch, the Ministry of the Environment, initiated a review of and revisions to the original guideline. The resulting guideline has eliminated any conflicts with other MOE guidelines and been expanded to include surface water sources.

It is recognized that conditions differ significantly from municipality to municipality and that strict adherence to these guidelines may not always be possible. Therefore, it is intended that these guidelines outline acceptable levels of servicing to assist consulting engineers, municipal engineering staff and other designers in the preparation of designs and applications that will meet the approval requirements of the Ministry of the Environment.

It should be noted that other approval authorities, such as the municipality which the works will be constructed, may have servicing standards that exceed the requirements of these guidelines. The designer should, therefore, ensure that he is aware of the requirements of all other approving authorities prior to making an application to the Ministry of the Environment.

As a final point, it must be emphasized that this document contains design guidelines. These should not be confused with standards or regulations which must be absolutely complied with in order to obtain a certificate of approval. It is not the intention of the Ministry of the Environment to stifle innovation. Whenever a designer can demonstrate that environmental and/or health conditions can be safeguarded by alternative approaches, such alternatives will be considered for approval.

1.0 GENERAL

1.1 For the purposes of this guideline a small water supply system or "minor" water supply system is defined as one which is designed to serve a population equivalent of less than 500 persons.

1.2 The decision as to when these communal water supply guidelines should be applied, should be decided by the municipality and/or regulatory agency. However, the following recommendations are provided for guidance:

a) Where an excess of ten residential lots or dwelling units are to be developed or exist and the average lot size is less than 0.8 hectares, a communal water supply system should be provided providing local conditions are favourable to the development of a suitable/acceptable ground or surface water supply.

b) Where in the case of a new subdivision, the lot size is to be 0.8 hectares or greater, individual wells may be allowed, unless the subdivision is located within or adjacent to a hamlet or settlement which may be provided with municipal supply in the future. In this case, as a minimum, watermains complete with house connections shall be provided at the time of installation of other services. It shall be the decision of the municipality as to whether a communal water supply shall be provided in the interim or whether private wells will be allowed.

1.3 The decision as to whether or not fire protection will be provided via the communal water supply system is a municipal responsibility. In deciding upon the need for such protection the municipality should consider such factors as:

a) The availability of adequate supply of water;

b) The additional capital and operating costs associated with such a system;

c) The availability of an adequate fire department, fire service communication and fire safety control facility;

d) Alternatives to a piped communal fire facility such as residential sprinkler systems.

Guidelines and advice respecting fire protection can be obtained from;

a) Insurers Advisory Organization
Fire Underwriters' Survey,
180 Dundas Street West,
Toronto, Ontario.
M5G 1Z9 (416) 597-1200

b) Ministry of the Solicitor General/Office of the
Fire Marshall Public Safety Division,
590 Keele Street,
Toronto, Ontario.
M6N 4X2 (416) 965-4848

1.4 Approval of all water supply and distribution plans and specifications must be obtained from the Ontario Ministry of the Environment prior to construction.

To aid in the obtaining of such an approval reference should be made to the Ministry's publication entitled "A Guide on Applying for the Approval of Water Works".

2.0 DOMESTIC WATER DEMAND REQUIREMENTS

2.1.1 Water use in small population centres/ subdivisions can be divided into the following sectors:

i) Household use, i.e., bathing, cooking, laundering, disposal of sanitary wastes.

ii) Outdoor use, garden and lawn irrigation, car washing, ornamental fountains, etc.

iii) Fire protection.

2.1.2 Average daily domestic consumption rates can vary from less than 180 L/c.d to more than a 1,500 L/c.d. These values represent the average flow over a 24 hour period and do not reflect the fact that there are maximum day and peak hour/instantaneous demands in the system each day which will exceed the average value by a significant amount. It is essential that the source of supply and the distribution system be capable of meeting these maximum and peak demand rates without overtaxing the source or resulting in excessive pressure loss in the distribution system.

2.1.3 Numerous studies have been undertaken in an attempt to establish the ratio between these average flows and the maximum and peak/ instantaneous rates. These studies have shown conclusively that small systems have a higher percentage maximum and peak demand rate than large systems, with rates as high as 15 times average.

2.1.4 Table I provides a summary of typical average domestic water use by type of establishment. Figure I contains a plot of number of dwelling units service vs. peak/instantaneous demand. Table I and Figure I have been adapted from those contained in the AWWA "Design and Construction of Small Water Systems - A Guide for Managers" and the Division of Sanitary Engineering, New York State Health Department "The Design of Small Water Systems" respectively. The values presented do not include an allowance for lawn watering.

2.1.5 The average domestic flow for a proposed service area should be calculated using the appropriate unit flow value(s) from Table I. As previously noted, these value(s) are the average flow over a 24 hour period. The maximum daily flow (i.e. the minimum flow for which the source of supply should be developed) should be calculated on the assumption that the average daily flow occurs over an eight (8) hour period. That is, a maximum day factor of three (3) times average day should be used.

2.1.6 The peak hourly/instantaneous demand rate should be determined by multiplying the average daily flow by the appropriate rate factor taken from Figure I.

2.1.7 As noted in the preceding clauses these flow figures are for domestic flows only and do not include allowances for lawn watering or fire protection. Where lawn watering and/or fire protection are to be provided via the communal water supply and distribution facility, these flows will generally be provided through a water storage facility.

FIGURE 1

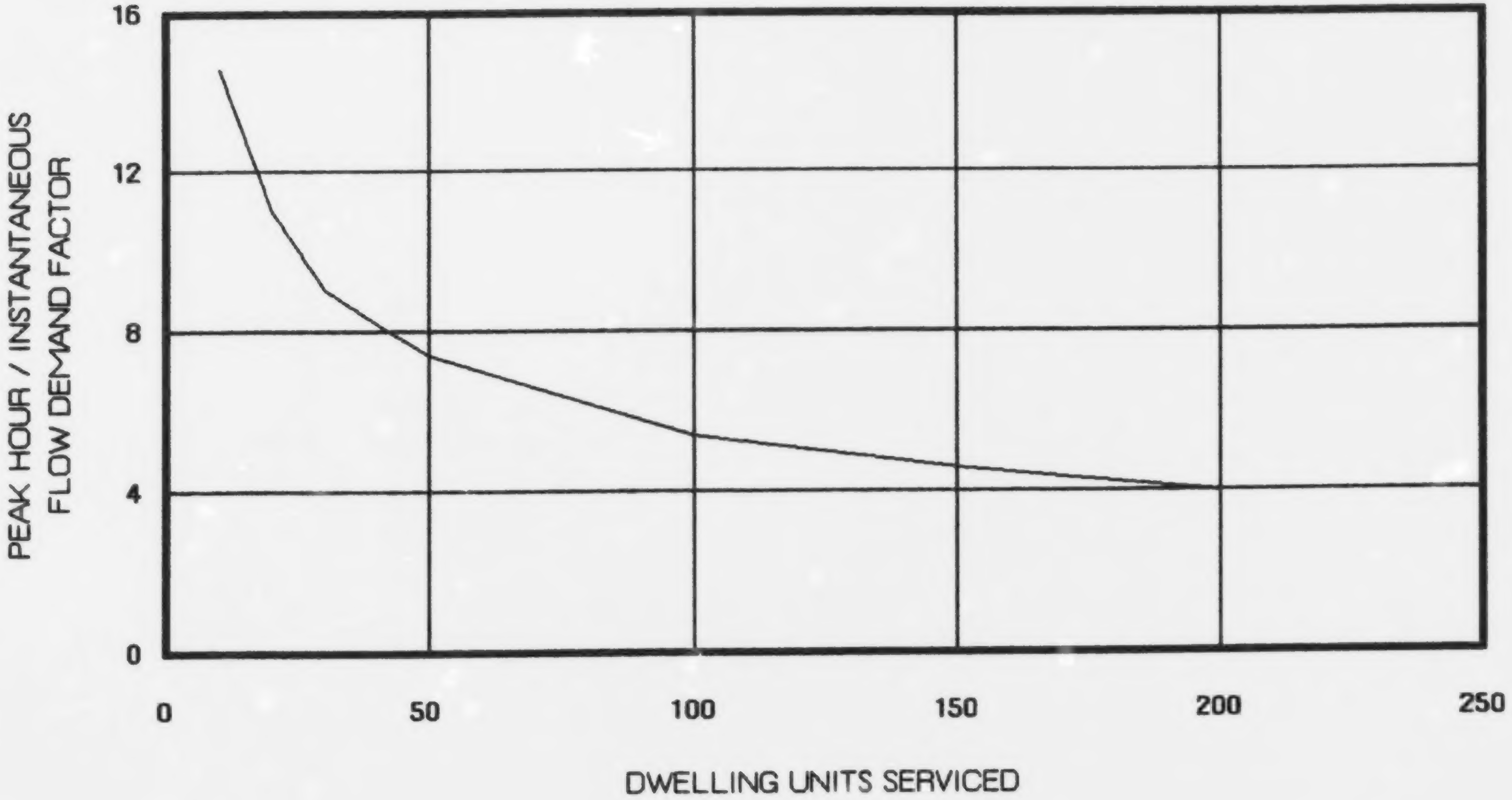
PEAK HOUR / INSTANTANEOUS
FLOW DEMAND FACTOR
16
12
8
4
0
0
50
100
150
200
250
DWELLING UNITS SERVICED

TABLE I
(Excluding lawn watering)
GUIDE FOR WATER USE

Type of Establishment	Water Used (L/day)
Camp:	
Construction, semi-permanent (per worker)	190
Dwelling:	
Boardinghouse (per boarder)	190
Luxury (per person)	380-570
Multiple-Family Apartment (per resident)	150
Roominghouse (per resident)	225
Single family (per resident)	190-285
Estate (per resident)	380-570

2.2 The number of persons occupying a particular type of housing unit will vary from population centre to population centre. Where the proposed service area involves an existing established population centre, an actual house count/population determination should be undertaken complete with an assessment as to the existence of vacant developable lots which would front or reasonably be connected to the system via extensions at some time in the future.

Where the proposed service area does not exist (i.e., plan of subdivision) reference should be made to similar types of development; the "Municipal Directory" etc. in order to permit a population determination. In the absence of such information however, the following is provided for guidance:

Type of Unit	Occupants/Units
Single Family	3.6
Semi-Detached	3.8
Duplex	3.8
Triplex	3.8
Townhouse	3.8
Apartment	2.8

2.3 The applicant (i.e., developer, consulting engineer, etc.) shall be responsible for the required application to the Ontario Ministry of the Environment for a Permit to Take Water where the daily withdrawal rate will exceed 50 m^3/d. The applicant shall be responsible for all conditions imposed by the Ministry in the Permit including compensation to other persons should the taking of water interfere with another persons interest in the water.

2.4 Where two service areas containing communal systems abut, interconnection of the distribution systems with a suitable operating agreement between the respective owners/operators may be allowed.

2.5 In some instances, particularly new development, it may be desirable to phase the construction of the water supply and distribution facilities over a period of time. Such phasing is acceptable to the Ministry providing the proponent is able to satisfy the Ministry that:

a) The proponent has title to all lands necessary for the construction of future phases;

b) The initial design and construction is such as to permit the construction of the future phases without interruption of service to the preceding phases; and,

c) The proposed source of supply has the potential to sustain the ultimate water supply requirement. In this regard it should be noted that any Permit-To-Take-Water issued by the Ministry for the source of supply may have conditions attached to it.

3.0 WATER SUPPLY AND STORAGE REQUIREMENTS

3.1 As a minimum the water supply facility should be designed to meet the projected maximum daily flow requirement of the service area with peak hourly, lawn watering and fire demands met from storage. Where it is possible to develop the source of supply to meet more than the projected maximum daily flow, this is acceptable and the required storage volume can be reduced accordingly.

3.2 When treatment of the water is required in order to meet the Ministry's Drinking Water Objectives the capacity of the treatment units should be increased by 5% in order to allow for in-plant uses such as filter backwashing, clarifier/settling tank blowdown, service water, etc.

3.3 Whether or not fire protection is required is a municipal decision. If the municipality has decided that fire protection is not to be provided and the source is only capable of the maximum day, the minimum effective storage to be provided shall be the average daily flow. To this minimum value must be added the appropriate allowances for lawn watering disinfection (as per MOE "Chlorination of Potable Water Supplies/65-W-4"); and, in-plant process requirements (when treatment required) as the individual proposal may require.

3.4 Where it has been decided that fire protection is to be provided via the communal water supply and distribution system the minimum volume of the storage facility should be increased by an amount equal to a fire flow of 16.6 L/s for 2 hours. This flow is the minimum recognized by the Insurers Advisory Organization - Fire Underwriters Survey for the purposes of rating. It is strongly recommended by the Ministry that discussions be held with both the Fire Underwriters Survey and the Office of the Fire Marshall respecting fire protection if the decision is made to provide fire protection via the communal system.

3.5 For lawn watering in other than luxury/estate type development it should be assumed that a maximum of 25% of the lots will be irrigating at any one time at a rate of 0.41 L/s for 1 hour per day (i.e., one sprinkler in operation). For luxury/estate type development it should be assumed that the rate of irrigation will be 0.57 L/s (i.e., two sprinklers in operation). The foregoing assumes that lawn watering is via portable sprinklers (a garden hose(s) and sprinkler(s)). If fixed irrigation systems such as pop-up-type or snap-valve-type are to be employed, reference should be made to the AWWA Publication entitled "Sizing Water Service Lines and Metres - AWWA No. M22" for demand criteria.

3.6 The allowance for lawn watering is not required where fire protection is provided via the communal water supply and distribution system.

3.7 For discussion respecting the design/layout of water storage facilities, reference should be made to the MOE publication entitled "Guidelines for the Design of Water Storage Facilities".

4.0 LOW LIFT PUMPING EQUIPMENT

4.1 When it is necessary that the raw water be subjected to treatment, low lift raw water pumps will generally but not always be required to pump the raw water from the source to the treatment facility. When low lift pumps are provided on a surface water source a minimum of two units, each capable of the design flow, should be provided.

4.2 Pumping of the raw water from the source to the treatment units should be accomplished via a submersible or vertical turbine pump. Operation of the low lift raw water pumps should be regulated by the utilization of high and low water level sensing devices located in the treated water storage reservoir. (The sensing devices should not contain mercury.)

4.3 Suitable control shall be provided for the low lift raw water pumps to operate each singly or together on automatic or manual modes.

4.4 In instances where a groundwater supply is to be utilized and this supply has been proven to be free of hazardous bacterial or viral contamination but still requires protective disinfection, provision should be made for a temporary direct connection between the low lift water pumps and the distribution system. This connection should be completed by a length of high pressure hose such that in the event of failure of the high lift pumping facility, it will be possible to maintain, albeit at a substantially reduced head, water service via the temporary connection. Under no circumstances should any form of by-pass capability between a low lift raw water pumping facility and a distribution system be provided when a surface water source is utilized as the source of supply.

4.5 The design of the low lift raw water pumping station discharge piping should be such as to minimize the number of high points. Any high points in the piping system should be equipped with a manually operated air relief valve which has been suitably threaded to permit the future installation of an automatic valve should this be found necessary.

4.6 Where treatment is required, the low lift/raw water pumps should be controlled such that the discharge rate to the treatment units does not exceed the capacity of the treatment unit(s) remaining in operation during backwashing. This can be accomplished by either providing sufficient additional storage at the treatment plant to permit complete shut-down of all treatment units during the backwash cycle or installing a rate-of-flow controller on the low lift pump discharge which throttles/limits flow to the treatment unit to a capacity equal to that of the unit remaining in service. In either case, the controls should be connected to the backwash pump cycle for automatic activation.

5.0 HIGH LIFT PUMPING EQUIPMENT

5.1 Where water treatment is to be provided, at least two high lift pumps must be provided with each pump designed to deliver a minimum of the design maximum day at the desired head.

5.2 Where fire protection is to be provided via the communal water supply/distribution facility, a third high lift pump (fire pump) shall be provided and the capacity of that pump shall be at least 16.6 L/s.

5.3 In many instances, it may be desirable to provide a third domestic high lift pump with this pump sized to meet a lesser flow rate than the maximum day requirement of the service area. In such instances, this domestic pump (lead high lift pump) should be designed to deliver the average daily flow for the service area.

5.4 In instances where the service area is not provided with an elevated storage tank and a ground storage reservoir located at the site of the treatment facility is the only storage provided, it will be necessary to provide pump(s) sized for the peak domestic demands.

5.5 During normal periods of domestic demand the smaller (average day) pump if provided, will provide an adequate supply of water, while the larger pumps (i.e., maximum day and/ or peak hour) will only operate to accommodate higher demands or in the event of failure of the lead (domestic) pump.

5.6 In instances where the storage for the system is in the form of a ground storage reservoir located adjacent to the source of supply, pump operations shall be controlled by pressure switches. Pressure regulation in the distribution system shall be accomplished by pressure regulating valves with pressure relief to the storage reservoir under low demand conditions. In many instances, it may be advisable to provide pressure tanks/cushioned tanks for pump control in order to minimize the number of start/stop cycles and hence, wear and tear on the pumping equipment.

5.7 Minimum system pressure of the highest point in the distribution system shall be 275 kPa under peak hour conditions. During periods of fire demand, the pressure in the distribution system should not fall below 140 kPa. The maximum pressure in the distribution system should not exceed 690 kPa.

6.0 ELECTRICAL EQUIPMENT

6.1 The preferred power supply to all water works is a three phase 550 volt source. Should this preferred source of power supply be unavailable for the proposed works, an acceptable alternate would be from a bank of three single phase distribution transformers with secondaries delta connected and ungrounded. Two transformers connected open delta are unacceptable.

6.2 All electric motors over 0.37 kW should be 575 volts, three phase, 60 hz. Motors should be provided with drip proof totally enclosed or submersible enclosures and the motor should be 2 CEMA standard MG-1 and be CSA approved.

6.3 Overload protection should be provided on each phase. All motor starters are to be combination type molded case breaker. Breakers should be equipped with adjustable magnitude trip only, (i.e., MCP type). Reduced voltage starters should be provided on all motors over 15 kW. Where 120 volt control is required with 575 volt starter, each starter should include an integral control transformer with a fused secondary.

6.4 All electrical apparatus should be located in an accessible location above grade with a clear access of 1.0 metres around all pumps and motors. This equipment should be mounted on a concrete base at least 150 mm above the floor level. Electrical conduit to the specifications of the electrical inspector should be used throughout the pumphouse. All panels and controls should be moisture resistant.

6.5 Heating of the pumphouse(s) should be by electrical unit heaters with individual built in thermostats. These heaters should be located within 1.0 m of the floor or be equipped with the appropriate fans and ducting to direct the heat to the floor area.

6.6 Fluorescent lighting should be provided in all pumphouses and should be located within 2.5 m of the floor in order to facilitate replacement of the fixture and/or tubes.

6.7 A single outside vandal proof light should be provided adjacent to or over the access door to the pumphouse(s). This light should be activated either by a photo electric cell or a timer.

6.8 A weather proof switch and electrical outlet should be provided inside the pumphouse immediately adjacent to the access door.

6.9 Lightning arresters should be provided at the 600 volt terminals at the hydro terminal pole.

6.10 In the case of a groundwater supply where one or more of the production wells is located external to the primary pumphouse, a lock out disconnect switch should be provided for each pump unit and these switches should be located within sight of the pump unit for which it is installed.

6.11 Standby power may be required at the supply and/or the high lift pumping facilities. To facilitate the assessment of the need for standby power by the Ministry, the following form should be completed.

INFORMATION REQUIRED FOR WATER PUMPING STATION APPLICATIONS

In order to assess the need for standby power at pumping stations, it is necessary to know details of the power supply to the pumping station(s). Complete the following questionnaire and submit it along with the application for approval.

A. ELECTRICAL POWER SUPPLY

i) The name of the operating authority of the power system at the point where the pumping station is tied in is ________________________________.

ii) The number of power feeder lines supplying the grid operated by this authority is ___________.

iii) The number of alternate routes possible within the power grid to supply the point of connection is ____.

iv) The number of alternate transformers through which power could be directed to power the pumping station in the event of failure of the major feed is ______________________________.

v) Is the service above ground? ________________.

vi) List the power abnormalities including power surges and drops during the past 5 years for the area of the pumping station.

Date	Duration	Reason for Abnormality

B. PUMPING STATION

i) The operating authority responsible for maintenance and operation of this pumping station is ______________________________.

ii) The power failure alarm is set up to relay a signal to ______________________________.

iii) The pumping station control __________ ("is" or "is not") equipped to automaticlaly re-start pumps in the event of their shutting down during power fluctuations and outages.

iv) Where the system is provided with elevated storage, the usable volume will provide _____ hours supply at average daily demand.

7.0 CONTROLS, INSTRUMENTATION AND METERING

7.1 The following controls shall be provided between the storage reservoir and the high lift and low lift pumping equipment:

(a) A low level cut-off to shut-off the high lift and fire pumping equipment when the water level in the reservoir drops to a pre-determined low level.

(b) A high level cut-off to shut down the low lift pumps when the water level in the reservoir has reached a pre-determined high level.

(c) Level sensors to operate the low lift pumps sequentially.

Note: Mercury switches should not be used in potable water systems.

7.2 Pressure switches shall be mounted on the discharge line from the high lift pumping station to operate the high lift pumping equipment sequentially. It is suggested that system pressure be maintained at 400 - 450 kPa utilizing the smaller of the high lift pumping units, with additional pumping units being called on when the demand/pressure drop dictates. Suggested call-on points are 340 kPa for the additional domestic flow pumps and 240 kPa for the fire pump. The maximum system pressure should not exceed 690 kPa.

7.3 A pressure gauge should be installed on the discharge of the high lift pumps.

7.4 Elapsed time meters should be provided for all high lift pumps.

7.5 Output from the high lift pumping station to the distribution system shall be metered with a recording type flowmeter calibrated in metric units. The recording device should be an electrically driven unit with a 7-day circular chart.

7.6 The start-stop operation of the fire pump should be arranged between the municipality and the local fire officials. Indication of the operation status of the pump should be relayed to an answering service or a central operating point where 24-hour surveillance is provided.

8.0 PUMPHOUSES

8.1 PUMPHOUSE - GENERAL

8.1.1 For each water supply installation, a suitable pumphouse of concrete block, pre-painted steel, or other suitable building material should be constructed. In all cases, the pumphouse should conform to local building and zoning by-laws as well as Ministry of Labour regulations. The size of the building should be such that all equipment is accessible for maintenance. A minimum 5.0 m^2 should be provided for the storage of chemicals. Building insulation should be in accordance with the Ontario Building Code.

8.1.2 If a frameless steel building is to be constructed, provision should be made to support wall-mounted equipment. This can be accomplished by providing a sub-frame suitably anchored to the concrete floor during initial construction. The exterior finish of steel buildings should be factory applied and baked prior to delivery. Should the steel building be of prefabricated, pre-insulated sections, the interior surface should be factory-coated and baked prior to delivery.

8.1.3 To discourage vandalism, no windows should be provided in pumping stations. In addition, all building locks should be of the flush-mounted type, deadbolt, and jimmy-proof. Keying arrangements should be as specified by the owner/operator. Heavy-duty type steel intake and exhaust louvres should be provided to minimize the potential for damage by vandals.

8.1.4 Ventilation of the pumphouses should be accomplished via an exhaust fan operated by a thermostat with a manual override switch. The exhaust outlet should be located on a wall near the ceiling, with inlet louvres located near the floor on the opposite side of the building. The inlet louvres should be controlled to open when the exhaust fan is operating, and to close when the fan is off. The exhaust fan should have sufficient capacity to provide 5-6 air changes per hour. The inlet louvres should be shrouded or otherwise protected from snow etc.

8.1.5 Raw and treated water sampling taps should be provided on the discharge lines from the low lift and high lift pumps. Treated water taps should be located at a sufficient downstream distance from chemical application points to ensure that complete mixing has taken place prior to the withdrawal of the samples.

8.1.6 All high lift pumps, motors, and cushion tanks should be placed on concrete bases at least 150 mm above the floor.

8.1.7 The building floor should be a minimum 300 mm above the external ground surface and/or any potential flood level. Pumphouse floors should be poured reinforced concrete and sloped towards the access door. Concrete floor slabs and pump bases should be sleeved from the pump shafts on vertical turbine pumps.

8.1.8 A fire extinguisher, Type ABC, should be provided in each building.

8.1.9 All interior and exterior wall surfaces, doors and trims should be painted to a colour scheme as approved by the owner/operator.

8.2 PUMPHOUSE - WELL PUMPING STATIONS

8.2.1 A hatch with minimum dimensions of 800 mm x 900 mm size should be provided in the roof of all well pumphouses directly over the well situated therein. The hatch may, if desired, be a removable type skylight unit. To allow for pump removal, the well should be positioned from 600 - 1200 mm from the outside of the wall, and be adjacent to an access road designed for heavy vehicle access. Double entrance doors should be provided, should open outwards, and should be sized such that they are wider than the largest piece of equipment in the pumphouse.

8.2.2 The elevation at the top of the well casing should be above the existing ground surface, the normal flood level of any adjacent water body, and at lest 0.15 m above the finished floor level of the pumphouse.

8.2.3 A pump pedestal, raised at least 0.15 m above the finished floor elevation, should be provided to support the full weight of the pump.

The weight of the well pump and its discharge assembly should not be borne by the well casing. Rather, this weight must be borne by the pump base and reinforced concrete floor slab.

8.2.4 The piping layout in the pumphouse should include an in-line free discharge pipe to the outside of the building to permit future test pumping of the well. The end of the pipe should be equipped with a free discharge pipe orifice and manometer tap, calibrated to the design yield of the well. Details respecting this discharge piping can be obtained from the Water Resources Branch - Drinking Water Section.

8.2.5 A combination flow control and check valve, calibrated to the design yield of the well, should be positioned in the well pump discharge header in advance of the free discharge pipe.

8.2.6 A digital flowmeter and recorder should be provided in the well pump discharge header in advance of the free discharge pipe.

8.2.7 Pressure gauges should be installed upstream and downstream of the flow controller.

8.2.8 A watertight seal should be provided between the pump base or submersible discharge header and the pump pedestal, or between the well casing and the pump discharge column.

8.2.9 Auxiliary openings, at least 25 mm in diameter, should be provided in the pump base, submersible discharge header, or well seal as required, to provide vertical access to the inner well casing for an electric sounder and the installation of accessory equipment.

8.2.10 The well should be equipped with an air vent. It should be vented to the outside of the building if explosive or toxic quantities of gas are present and the auxiliary holes sealed.

8.2.11 The well should be equipped with a water level measuring air line. The air line should be clamped to the pump column, provided with a direct reading pressure gauge in metres, and calibrated to the water level in the well.

8.2.12 At no time during the equipping and testing of the well pump is the rate of pumping to exceed the design yield of the well. Overpumping of a well can adversely affect the well's development and can result in decreased well efficiency and/or the pumping of sand from the well.

8.2.13 Appendix T contains "Criteria for Pumping Tests for Small Communal Groundwater Supplies" and should be referenced for guidance in development and contracting of small groundwater sources.

9.0 WATER SUPPLY PROPERTY AND ACCESS REQUIREMENTS

9.1 It is the preference of the Ministry that all property, structures, distribution system piping, and appurtenances associated with the water supply, storage distribution works be deeded to the municipality.

9.2 Actual property requirements should be negotiated prior to approval of the water supply system by the municipality. Property requirements will vary, but as a minimum, access for large service vehicles should be provided for, and space for temporary holding lagoons which will be required for acid waste waters during well maintenance.

9.3 All property associated with above-surface structures should be fenced with a chain link security fence at least 1.8 m high. The fencing material should be #9 gauge, 50 x 50 steel chain link wire fencing, galvanized following fabrication. A 3.6 m gate should be provided for vehicular access.

9.4 Access roads should be provided to each pumphouse, well head, and reservoir. These roads should be designed and constructed for year-round use.

9.5 Overhead electrical wires and the location of transformers must be situated in such a way as not to interfere with the operation of crane equipment over a well pumphouse or well heads.

10. WATER TREATMENT REQUIREMENTS

10.1 Water for drinking, culinary and other domestic uses should be safe, palatable and aesthetically appealing. It should be free from pathogenic organisms, hazardous levels of chemical ad radioactive substances. Other aspects, such as corrosivity, tendency to form incrustations, and excessive soap consumption due to hardness should be controlled on the basis of economic considerations as they can interfere with the intended domestic use of the water.

10.2 Ministry of the Environment Policy 15-06 of the Manual of the Environmental Policies and Guidelines deals with drinking water quality in Ontario. The policy applies to water works operated by the municipalities and others as covered under the provisions of Section 23 of the Ontario Water Resources Act. The main function of these works is to ensure that all surface and groundwater sources produce a potable water.

10.3 The Ministry's "Treatment Requirements for Municipal and Communal Waterworks Using Surface Water Sources" and "Treatment Requirements for Municipal and Communal Waterworks Using Groundwater Sources" are the Ministry's formal policies respecting these subjects. In essence it is required that all waterworks shall have acceptable source protection and treatment processes to ensure that the potable water produced meets the intent and limits set out in the "Ontario Drinking Water Objectives.

10.4 The proponent of any water supply facility, whether the source be surface or groundwater, should familiarize himself with the requirements of these policies and the Ontario Drinking Water Objectives in order to ensure that the proposed works comply with their requirements. Copies of these materials are available from the Ministry's District, Regional and Head Office, Water Resources Branch.

10.5 Disinfection of communal water supplies shall be in accordance with the Ministry's publication entitled "Chlorination of Portable Water Supplies-Bulletin 65-W-4".

11.0 WATER SYSTEM OPERATION

11.1 While recognizing that operation of communal water supply and treatment systems should be performed by municipal personnel, it is realized that in the interest of economy and security, operation of remote systems can be accomplished with on-site personnel retained on contractual basis. In the case of a privately operated water supply and treatment facility it should be clearly outlined in the agreement as to which method of operation is to be undertaken with appropriate clauses outlining "safe harmless" agreements, insurance coverages, leveling of water rates, and the possible takeover of operations by municipal personnel on default.

11.2 If the new water supply system is to be contractually operated, the municipality should levy on the private operator a yearly inspection fee to defray the cost of routine inspections by municipal personnel.

11.3 In the case of privately owned and operated facilities it should be understood that all capital costs of system construction should be recovered through the sale of lots and revenues obtained from the sale of water should only cover operating, maintenance and collection costs.

11.4 An operating manual must be prepared and turned over to the municipality. This manual must contain at least the following:

a) as constructed civil, mechanical and electrical drawings.

b) As constructed building and laboratory details.

c) As constructed distribution system drawings.

d) Pump literature, pump curves and operating instructions.

e) Operating and maintenance instructions for all equipment.

f) Names, addresses and telephone numbers of all equipment suppliers and installers.

g) Information on guarantees/warranties for all equipment.

h) The name, address and telephone number of the designer.

i) The name, address and telephone number of the nearest Ministry of the Environment and Ministry of Health offices as well as the municipal officials.

12.0 DOMESTIC WATER METERING AND WATER SERVICES

12.1 It is well known that the use of domestic water meters is effective control of wasteful water use. A municipality should therefore strongly consider the installation of water meters in all new homes being served with a communal water supply. To reduce costs of meter reading, readout devices should be placed near the hydro and/or gas meter at the time of water meter installation.

12.2 A metered water rate with appropriate service charges, if required, should be established to provide revenue for the costs associated with the operation, maintenance and collection based upon anticipated consumption patterns. The rate should also allow for a contingency fund to cover future repairs, maintenance, upgrading etc.

12.3 The minimum water service size shall be NPS-3/4. The local municipality however may direct a larger service to be installed under the following conditions:

a) Larger homes for larger instantaneous water demands can be expected (e.g. estate type development).

b) A length of service lateral is in excess of 30 meters.

c) The pressure in the distribution system is low.

12.4 The municipalities shall designate the materials to be used in the installation of service connections.

GUIDELINES FOR THE DESIGN
OF
SEASONALLY OPERATED
WATER SUPPLY SYSTEMS

FEBRUARY 1985

ENVIRONMENTAL APPROVALS AND PROJECT ENGINEERING BRANCH

The Honourable
Jim Bradley
Minister

Allan E. Dyer, Ph.D., M.D.
Deputy Minister

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The initial issue of these guidelines was prepared in 1982 by the Municipal and Private Approvals Section, Environmental Approvals Branch.

The February 1985 issue of the guideline was edited in format to conform to the overall MOE Design Guideline format by Special Engineering, Design and Equipment, Environmental Approvals and Project Engineering Branch. In addition, revisions/updating of the section dealing with design flows are incorporated.

1.0 INTRODUCTION

Par 1 For the purposes of this guideline, a seasonally operated water works is defined as a water works which operates on a seasonal (summer) basis only, and is taken out of service/operation each fall and returned to service/operation each spring.

Par 2 This guideline has been prepared to document the desirable requirements for the servicing of seasonally operated water supply systems requiring approval from the Ministry of the Environment which have an ultimate or design population not exceeding 500 persons.

Par 3 A complete documentation of all the parameters relating to the design of seasonally operated systems is beyond the scope of these guidelines, but an attempt has been made to address the areas of greatest importance to ensure that a reliable system will be provided which produces a reliable potable supply for the consumers.

Par 4 By issuing these guidelines, it is not the intention of the Ministry of the Environment to stifle innovation. Where the designer can show that alternate approaches can produce the desired results, such approaches will be considered for approval.

Par 5 The mention in the following text to specific documents is not intended to imply that these represent the sole or most highly regarded sources of information. They may, however, be regarded as a starting point for the designer who may wish to use these documents in conjunction with his own experience to complete the design.

Par 6 Designers are advised to familiarize themselves with the requirements of all legislation dealing with waterworks systems, their associated equipment and labour safety requirements.

2.0 LEGISLATIVE AUTHORITY

Par 1 There is a requirement under the Ontario Water Resources Act, for the proponent to submit to the Ministry of the Environment a formal application for approval of the proposed waterworks system together with detailed final engineering plans, specifications and appropriate design calculations prior to construction of the works. Further, detailed data are required on water quality and quantity aspects of the source of supply. Please note that construction of the proposed works is not to proceed until such time as all required certificates and permits have been issued. The only exception to the foregoing is the construction and development of a well. That is, it is permitted to construct and develop a well without a Certificate of Approval under Section 23. However, the well must not be equipped and/or put into service until the Certificate of Approval is issued.

Par 2 Copies of the "Application for the Approval of Water Works" can be obtained from the Ministry of the Environment. This application, together with all supporting documentation, should be submitted to the Environmental Approvals and Project Engineering Branch - Environmental Approvals Section. A duplicate copy of the submission should be sent to appropriate Ministry Regional or District Office. It is recommended that the proponent discuss the proposed development with Ministry staff prior to proceeding to make a formal submission.

Par 3 The proponent/owner-operator shall be responsible for the required application to the Ontario Ministry of the Environment for a Permit to Take Water where the daily withdrawal will exceed 50 m^3/d. The proponent shall be responsible for all conditions imposed by the Ministry in the Permit including compensation to other persons should the taking of water interfere with another person's interest in the water.

Par 4 All enquiries regarding approval of works should be directed to the Environmental Approvals Section, Environmental Approvals and Project Engineering Branch.

3.0 WATER SUPPLY REQUIREMENTS

Par 1 Water use in seasonal water supply systems can be divided into the following sectors:

i) Household use, i.e., bathing, cooking, laundering, disposal of sanitary wastes.
ii) Outdoor use, i.e., garden and lawn watering, car washing, etc.
iii) Fire protection.

Par 2 Average daily domestic consumption can vary from less than 180 L/c.d to more than a 1,500 L/c.d. These values represent the average flow over a 24 hour period and do not reflect the fact that there are maximum day and peak hour/instantaneous demands in the system each day which will exceed the average value by a significant amount. It is essential that the source of supply and distribution system be capable of meeting these maximum and peak demands without overtaxing the source or resulting in excessive pressure loss in the distribution system.

Par 3 Numerous studies have been undertaken in an attempt to establish the ratio between the average flow and the maximum and peak/instantaneous demand. These studies have shown conclusively that small systems have a higher percentage peak demand flow than large systems, with rates as high as fifteen (15) times average.

Par 4 Table I (following this section) has been abstracted from the American Water Works Association publication entitled "Design and Construction of Small Water Systems

- A Guide for Managers", and presents a summary of average water use.

Par 5 For the purposes of determining the average flow for seasonal systems (population 500), the appropriate value(s) in Table I should be used.

Par 6 If it is proposed not to provide water storage facilities for the development, the source of supply should be developed to meet the peak hourly rate.

Par 7 If it is proposed to provide water storage facilities, the source of supply should be developed to meet the maximum daily flow. (Note: The foregoing values do not allow for lawn watering or fire protection.)

Par 8 If lawn watering is to be allowed/take place, reference should be made to Section 3.5 of the MOE "Guidelines for the Design of Water Supply Systems for Small Residential Development". This additional rate/volume can be provided via either the source of supply proper or through the construction of a reservoir.

Par 9 Where fire protection is to be provided via the communal water supply and distribution facility, the required fire flows are generally provided through a water storage facility (i.e., ground or elevated storage).

Par 10 Alternative design flow criteria will be considered by the Ministry for extensions to existing seasonal systems providing the proponents data is within reasonable bounds and is concurred with by the Ministry's Regional and

District Office. In assessing these alternative design flow criteria, the Regional and District Offices will consider existing water quality; the existing source capacity as opposed to the existing level of service/facilities available; the presence/absence of complaints respecting water supply problems (i.e., low pressure, shortages, etc.) and facilities to be provided with the extension when compared to the existing facilities.

Par 11 In some instances it may be desirable to phase the construction of the water supply and distribution system. Such phasing is acceptable to the Ministry providing the proponent is able to satisfy the Ministry that:

a) The proponent has title to all lands necessary for the construction of the future phases;

b) The design and construction of the initial phase is such as to permit the construction of the future phases without unnecessary interruption of service to preceding phases; and

c) The proposed source of supply has the potential to sustain the ultimate water supply requirement. In this regard it should be noted that any Permit-to-Take-Water issued by the Ministry for the source of supply may have conditions attached to it.

Par 12 For information on well development, the proponent may wish to contact the Technical Support Section of the appropriate Ministry Regional Office. Also reference should be made to Appendix T "Criteria for Pumping Tests for Small Communal Ground-Water Supplies".

TABLE I

(Excluding lawn watering)
GUIDE FOR WATER USE

Type of Establishment	Water Used (L/day)
Camp:	
Construction, semi-permanent (per worker)	190
Day, no meals served (per camper)	60
Luxury (per camper)	380-570
Resort, day and night, limited plumbing (per camper)	190
Tourist central bath and toilet facilities (per person)	135
Cottage, seasonal occupancy (per resident)	190
Court, tourist, individual bath units (per person)	190
Club:	
Country (per resident member)	380
Country (per non-resident member present)	95
Park:	
Overnight, flush toilets (per camper)	95
Trailer, individual bath units, no sewer connection (per trailer)	95
Trailer, individual baths, connected to sewer (per person)	190
Picnic:	
Bathhouses, showers, and flush toilets (per picnicker)	75
Toilet facilities only (per picnicker)	40
School:	
Boarding (per pupil)	285-380
Day, cafeteria, gymnasiums, and showers (per pupil)	95
Day, cafeteria, no gymnasiums or showers (per pupil)	80
Day, no cafeteria, gymnasiums, or showers (per pupil)	60

4.0 SOURCE CAPACITY AND STORAGE REQUIREMENTS

Par 1 As a minimum, the source of supply for the development should be developed and equipped to meet a maximum daily flow requirement of four (4) times the average daily flow.

Par 2 It is necessary however, that the system be capable of meeting a peak hourly rate equivalent to the average daily flow times the appropriate peak flow factor from Figure I.

Par 3 In instances where the source of supply cannot be developed to meet this peak hourly rate or circumstances dictate that this is not economical, water storage facilities should be provided to make up the difference.

Par 4 As a minimum, the water storage facilities should be sized to provide a usable volume equivalent to the average daily flow. As previously noted, this volume does not allow for lawn watering or fire protection.

Par 5 The decision as to whether or not fire protection is to be provided via the communal water supply and distribution system rests with the owner of the development and the municipality in which the development is located.

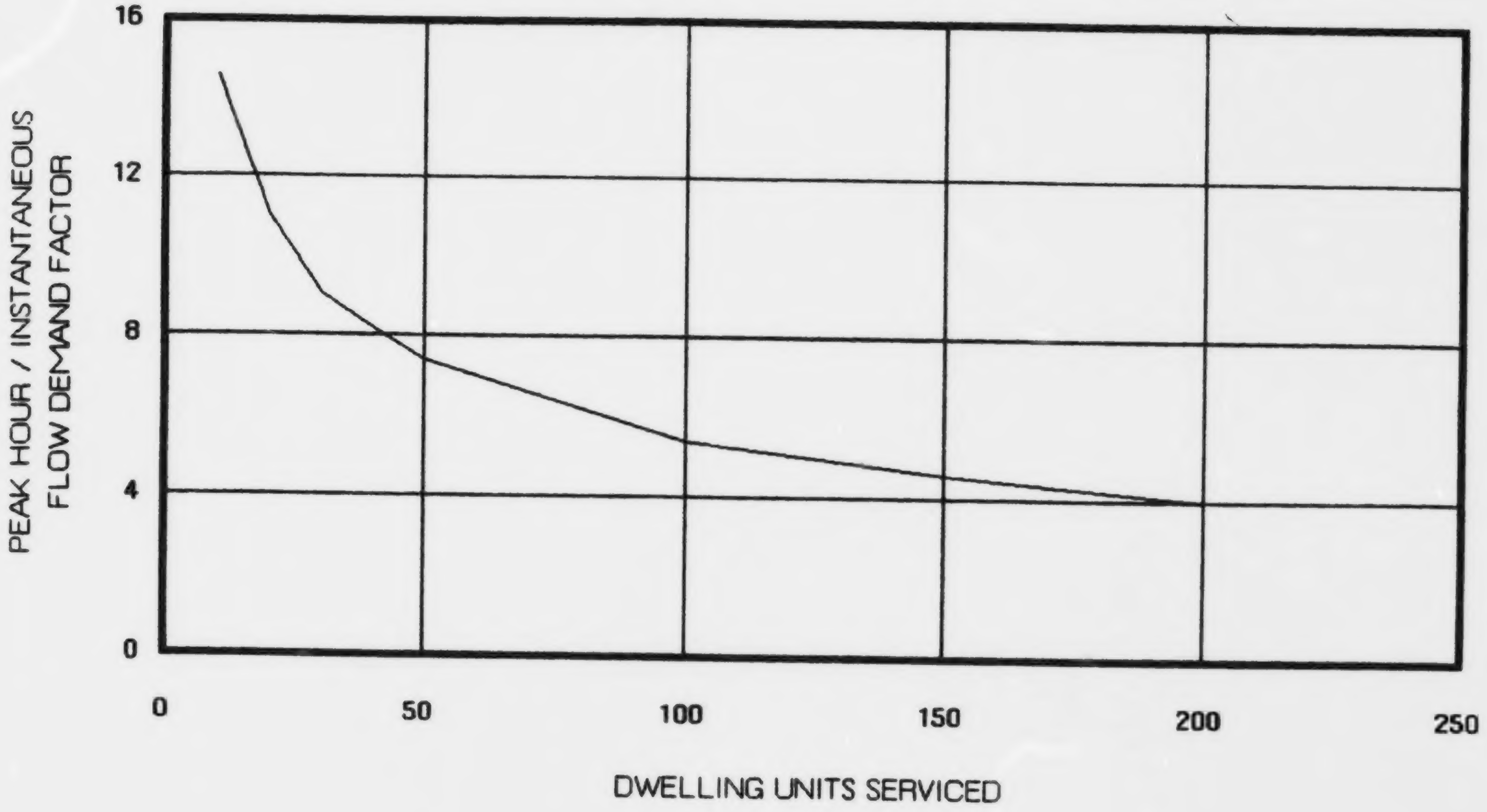
Par 6 The owner should consult with his insurer as to the fire protection requirements, etc., of his liability insurance, and with the municipality.

Par 7 As a minimum, the Ministry would recommend that where fire protection is to be provided the storage facility be increased in size by a volume equal to a fire flow of 16.6L/s for two (2) hours.

Par 8 The total installed pumping capacity at the source of supply and the storage facility, where it is not elevated storage, should be equal to the peak hour rate plus any additional capacity necessary to meet additional flows such as lawn watering or fire protection where these are designed for.

Par 9 For guidance related to the physical layout and design of water storage facilities, reference should be made to the MOE "Guidelines for the Design of Water Storage Facilities."

FIGURE 1


PEAK HOUR / INSTANTANEOUS FLOW DEMAND FACTOR
16
12
8
4
0
0
50
100
150
200
250
DWELLING UNITS SERVICED

5.0 DISTRIBUTION SYSTEM

5.1 GENERAL

Par 1 The spacial separation of watermains and sewage works shall be in accordance with Appendix F.

Par 2 The minimum recommended watermain distribution size should be NPS-2. This assumes no fire flow is required.

Par 3 The minimum pressure rating for water distribution system piping should be 690 kPa.

Par 4 The distribution system should be looped to eliminate dead-ends and/or provided with suitable blow-off facilities.

Par 5 The distribution system should be buried sufficiently to minimize the possibility of vandalism or physical damage occurring. Suitable protection should be provided for road crossings to prevent crushing of the watermain.

Par 6 The water distribution system should be provided with suitably located air release valves, blow-offs, isolation valves, and drain chambers to facilitate flushing and draining the system in the fall and purging and disinfection of the system in the spring.

Par 7 Information should be provided on the type of bedding material, where same is required, and details on the thrust blocking for the watermain distribution system.

Par 8 If a fire flow is required, or may be required in the future, a minimum NPS-6 diameter watermain should be provided.

Par 9 Refer to:

"Guidelines for the Design of Water Storage Facilities", and "Water Distribution Systems".

5.2 RESIDUAL PRESSURE IN DISTRIBUTION SYSTEM

Par 1 A minimum residual pressure of 275 KPa should be provided in all sections of the water distribution system under conditions of peak hour demand when no fire flow allowance is made.

Par 2 If fire flow is provided, a minimum residual pressure of 140 KPa is required under a condition of maximum day demand plus fire flow demand with pressures ranging between 350 KPa and 550 KPa under a condition of maximum daily flow.

Par 3 Where the topography of the proposed seasonal works has considerable variation it may be necessary for the proponent to undertake a detail distribution system network analysis in order to ensure that the foregoing residual pressures exist.

NOTE: NPS = Nominal Pipe Size

6.0 SYSTEM OPERATION

Par 1 It is preferred that all new seasonal water systems be owned and operated by the municipality in which they are constructed. Where it is the intention of the proponent (i.e., private individual or company) to maintain ownership and operating responsibility, the proponent should contact the Ministry's Regional Office to discuss ownership and operation.

Par 2 For trailer park type development, an operating agreement should be entered into by the owner and the municipality to ensure the continued safe operation of the system.

Par 3 Where two service areas containing communal systems abut, interconnection of the distribution systems with a suitable operating agreement between the respective owners/operators may be allowed.

7.0 PUMPHOUSE

Refer to:
"Guidelines for the Design of Water Supply Systems for Small Residential Developments".

8.0 SAMPLING

8.1 WELL SUPPLIES

Par 1 Representative raw water samples are to be collected for physical, chemical and bacteriological analyses from each well supply at the beginning and end of each pumping test.

Par 2 Representative raw water samples are to be collected for water quality assessment and analyzed for those bacteriological parameters as noted in the publication entitled, "Ontario Drinking Water Objective". A sterilized 200 ml bottle should be used for the purpose of sample collection for bacteriological examination.

Par 3 Representative raw water samples are to be collected for water quality assessment and are to be analyzed for those physical and chemical parameters as noted in the publication entitled, "Ontario Drinking Water Objectives". It is recommended that the proponent check with the Ministry of the Environment to determine the amount of sample to be collected and any requirement for addition of a preservative. Typically, water for chemical analyses is collected in one litre bottles.

8.2 SURFACE WATER SUPPLIES

Par 1 Complete raw water quality analyses (chemical, physical and bacteriological) are required for a period of time sufficient to provide an accurate assessment of the raw water quality. The appropriate Regional Office of the Ministry of the Environment should be contacted prior to commencing the sampling programme for guidance respecting the extent of sampling, the duration of sampling, the number of samples, the parameters to be analyzed for etc.

9.0 WATER QUALITY

Par 1 The quality of water supplied to the consumers on a seasonally operated water system shall meet the Ministry of the Environment "Ontario Drinking Water Objectives". The list of water quality parameters can be obtained from the afore mentioned document. The proposed source (well or surface supply) is to be tested for all of the parameters listed unless specific parameter exemptions are given by the Ministry of the Environment.

Par 2 Sufficient treatment facilities are required in the pumphouse or an adjacent structure to ensure that the treated water entering the distribution system meets the Ministry's drinking water objectives as noted in the above referenced document.

Par 3 The nature of, and degree of treatment required on a seasonal water supply will be assessed on a case-by-case basis. The proponent should contact the Ministry's Regional or District Office to receive direction/guidance respecting the water treatment requirements for his/her specific application.

Par 4 A seasonal water supply and distribution system shall be disinfected each season. Following disinfection, and prior to the system being placed into operation, samples shall be collected from the disinfected system, in accordance with the "Ontario Drinking Water Objectives", and submitted to the Ministry of the Environment or a laboratory acceptable to the Ministry for bacteriological examination. The system must not be placed into operation until acceptable results are obtained. Any adverse/positive results will necessitate repeating of the disinfection and sampling/analysis until all analysis are negative.

NOTES

Reference should be made to the following MOE Publications:

1. "Minimum Treatment Requirements for Potable Water Supplies from Surface Water Sources".
2. "Minimum Treatment Requirements for Potable Water Supplies from Ground Water Sources".
3. "Chlorination of Potable Water Supplies".
4. "Guidelines for the Design of Water Treatment Works" for information on treatment requirements for water supplies.
5. "Water Quality in Distribution Systems - Problems and Maintenance/T.N. #7018".

10.0 SEWAGE COLLECTION AND TREATMENT

Par 1 An approved method of sewage collection and treatment is required for all seasonally operated systems. If the proposed treatment system discharges to a surface water approval under Section 24 of the Ontario Water Resources Act, R.S.O. 1980, is required. If the proposed treatment system is subsurface disposal, approval under Section VII of the Environmental Protection Act is required.

Par 2 Sewage collection and treatment requirements for each proposal will be determined on a case-by-case basis. The Ministry's Regional or District Office should be consulted for direction/guidance in this regard.

11.0 OPERATION'S MANUAL

Par 1 A detailed operation's manual should be provided for all systems. This manual should contain the following information:

1. "As Built" plans and sections of the pumphouse and equipment installed therein.
2. "As Built" location plans of the distribution system showing location, appurtenances, etc.
3. Specifications on all equipment in the pumphouse including the manufacturer's name, model number, serial number and operation instructions.
4. Name, address and phone number of all equipment suppliers.
5. Basic "trouble shooting list" for each component.
6. Step-by-step procedures for making up stock solutions.
7. Detailed information on all system process operations.

Par 2 In addition to the foregoing, it will be necessary for the owner/operator to maintain records respecting his maintenance programme and operating/sampling programme. The Ministry's Regional or District Office should be consulted respecting those records and the sampling programme.

12.0 ENVIRONMENTAL ASSESSMENT ACT (EAA)

Par 1 Consultations should be undertaken with the Ministry of the Environment's Environmental Assessment Branch to determine whether or not the proposed works are subject to the EAA.

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APPENDIX "A"

EXTRANEOUS FLOW ALLOWANCES

In the design/assessment of any sanitary sewerage works facility there should be an allowance made for extraneous flows. (i.e., infiltration/inflow). The absolute value utilized in any specific system design/assessment will vary depending upon local conditions and/or the nature of the application of the infiltration allowance (i.e., sewer design; sewage pumping station design; sewage treatment plant design; existing sewerage works assessment and acceptance testing of new sewers).

In this Appendix the customary or design units are stated under each heading. Based on a typical plan of subdivision these customary units have been converted to "equivalents" for illustrative purposes only.

Acceptance Testing of New Sewers

Division 410 of the Ontario Provincial Standard Specification lists an allowable extraneous flow/leakage (infiltration/exfiltration) of 0.075 litres/millimetre diameter per 100 metres of sewer per hour.

This "customary" unit converts to the following based on the typical plan of subdivision.

a) 22 L/cap.d
b) 0.01 L/ha.s

Sewer Design

Typically, in the design of a sanitary collection sewer system a peak extraneous flow allowance of between 0.10 and 0.28 L/ha.s is made. These customary units, when applied to a typical plan of subdivision convert to the following values.

a) 0.72 to 2.03 L/mm Ø/100 m/hr*
b) 212 to 593 L/cap. d

* total sewer system including main sewers, service connections and building sewers.

The above-noted design value is for new collector sewer systems and assumes;

a) Strict control by the municipality of building sewer connections (i.e., no roof drains or foundation drains connected directly or indirectly to the sanitary sewers).

b) Adequate design and inspection during the construction of the public sewers and the private connections.

c) A routine inspection and maintenance programme will be undertaken by the municipality/operating authority to ensure that a "tight" sewer system is maintained.

Sewage Pumping Stations and Sewage Treatment Works

As with the design of new sanitary collector sewers it is accepted practice to make an allowance for extraneous flows in the design of any sewage pumping station or sewage treatment facility. However, as the design period for pumping stations and treatment facilities is generally less than that of the sewers (i.e., 10-20 years vs 20-40 years) a lesser extraneous flow allowance should be used. Also, while the allowance is made in sewer design it is assumed that the actual volumes received will be substantially less because of the controls and inspections which are undertaken during and after construction.

Therefore, in the design of any new pumping station or treatment facilities complementary to a new collector sewer system an extraneous flow allowance of 90 L/cap. d (average) and 227 L/cap.d (peak) should be made.

This design value, when applied against the typical plan of subdivision, is approximately equivalent to;

a) 0.043 L/ha. s (average) - 0.107 L/ha. s (peak)
b) 0.308 L/ha. s (average) - 0.776 L/mmØ/100 m/hr (peak)

Assessment of Existing Sewage Works

The capital and operating costs associated with new sewerage works facilities are increasing steadily. In addition, the Ministry's "Water Management - Goals Policies, Objectives and Implementation Procedures of the Ministry of the Environment" requires that all Certificates of Approval for new sewage treatment facilities contain the effluent requirements for the facility.

Accordingly, studies to ascertain the extent and source of extraneous flows are becoming more important.

Experience in the United States has indicated that if the extraneous flow, based upon the highest weekly average within a 12 month period, is less than 140 L/mm.km.d, rehabilitation of the sewer system will not be economical.

Based upon the preceding typical plan of subdivision this value of 140 L/mm.km.d is approximately equivalent to

a) 0.08 L/ha.s
b) 171 L/c.d

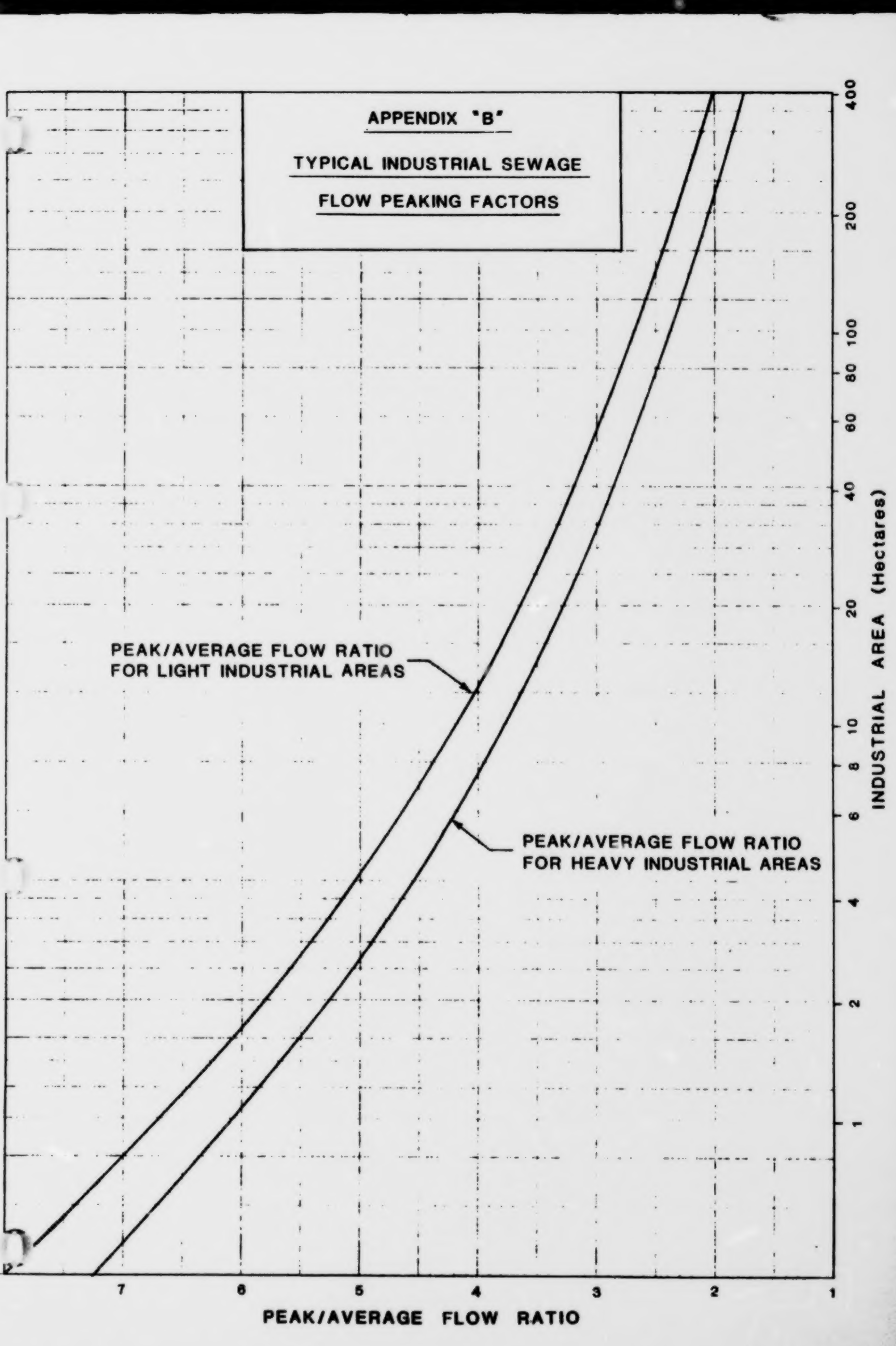
NOTES:

1. The "typical" plan of subdivision has the following characteristics.

Overall Area -	23 ha
Total Lots/Units -	263
Typical Set Back -	7.6 m
Population Density -	3.0 persons/lot (unit)
Main Sewer length and size -	3072 m of NPS-8*
Sewer lateral length and size -	2645 m of NPS-5*
Building sewer length and size -	2004 m of NPS-4*

*Nominal pipe size is indicated with a NPS designator number.

2. Critical in reducing the volume and rate of flow to be handled by a foundation drainage system and hence, its ability to keep a basement dry is lot grading. Therefore, in all new development, every effort should be made to ensure that the lot is drained away from the foundation walls.



APPENDIX "B"

TYPICAL INDUSTRIAL SEWAGE FLOW PEAKING FACTORS

SANITARY SEWER DESIGN SHEET

APPENDIX C

q = average daily per capita flow (___ L/cap. d)
I = unit of peak extraneous flow (___ L/ha. s)
M = peaking factor
Q (p) = peak population flow (L/s)
Q (i) = peak extraneous flow (L/s)
Q (d) = peak design flow

$M = 1 + \frac{14}{4 + \sqrt{P}}$ where P population in 1000's

$Q(p) = \frac{PqM}{86.4}$ (L/s)

$Q(i) = IA$ (L/s) where A = area in hectares

$Q(d) = Q(p) + Q(i)$ (L/s)

LOCATION			INDIVIDUAL		CUMULATIVE		Peaking factor M	Pop. flow Q(p) (L/s)	Peak extraneous flow Q(i) (L/s)	Peak design flow Q(d) (L/s)	PROPOSED SEWER						
STREET	FROM	TO	Pop.	Area A (hectares)	Pop.	Area A (hectares)					Length (m)	Pipe size (mm)	Type of pipe	Grade %	Capacity (L/s) n = ___	Full flow velocity (m/s)	Actual velocity at Q(d)

	DESIGN	PROJECT	SHEET No.
	CHECKED		___ of ___
	DATE		

APPENDIX C

STORM SEWER DESIGN SHEET

Q 2.78 AIR
Where Q peak flow in litres per second (L/s)
A area in hectares (ha)
I rainfall intensity in millimetres per hour (mm/h)
R runoff coefficient

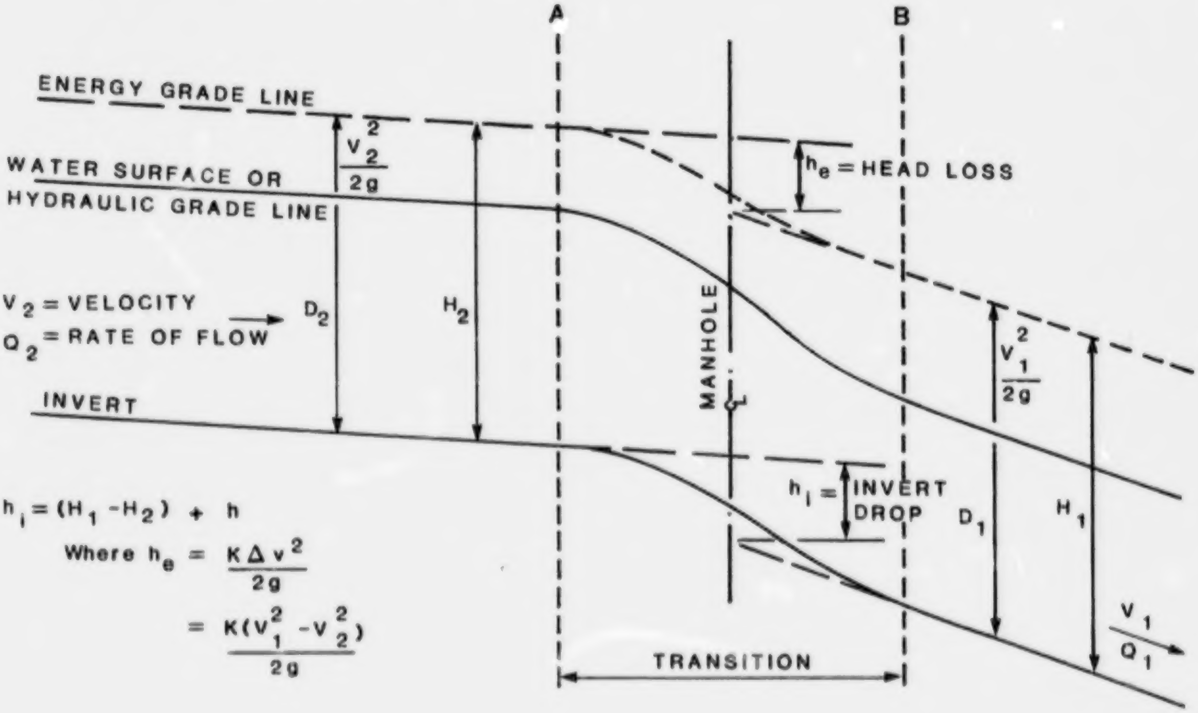
LOCATION			AREAS (ha)			indiv. 2.78 AR	Accum 2.78 AR	Time of Conc.	Rainfall Intensity I	Peak Flow Q (L/s)	SEWER DATA							
STREET	FROM	TO	R =	R =	R =						Diameter (mm)	Slope (%)	Length (m)	Capacity (L/s) n =	Velocity (m/s)	Time of Flow (minutes)		

DESIGN	PROJECT	SHEET No.
CHECKED		— of —
DATE		

APPENDIX D

HYDRAULIC CALCULATIONS FOR JUNCTION AND TRANSITION MANHOLES

CRITERIA AND BASIS OF DESIGN


A
B
ENERGY GRADE LINE
$\frac{V_2^2}{2g}$
WATER SURFACE OR HYDRAULIC GRADE LINE
h_e = HEAD LOSS
V_2 = VELOCITY
Q_2 = RATE OF FLOW
D_2
H_2
MANHOLE
$\frac{V_1^2}{2g}$
INVERT
h_i = INVERT DROP
D_1
H_1
V_1
Q_1
TRANSITION

$$h_i = (H_1 - H_2) + h$$

$$\text{Where } h_e = \frac{K \Delta v^2}{2g} = \frac{K(v_1^2 - v_2^2)}{2g}$$

K = 0.1 FOR INCREASING VELOCITY CHANGE

K = 0.2 FOR DECREASING VELOCITY CHANGE

ASSUMPTION

Manhole length is relatively short so that h_i can effectively be taken to be the actual drop in inverts at the extremes of the manhole.

METHOD

1 Each incoming pipe must be analyzed separately together with the outgoing pipe.

2. Employ Hydraulic Elements Chart (Figure 1, last page this Appendix) for % depth of flow and % velocity.

3. The designer should, wherever possible, restrict the change in velocity to not more than 0.6 m/s in special cases, consideration should be given to bellmouth entrances.

4. Complete the hydraulic calculations outlined in the following.

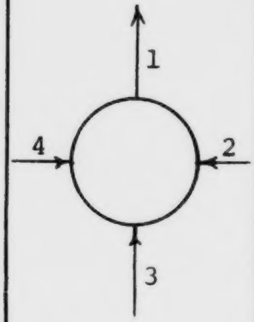
HYDRAULIC CALCULATIONS
FOR
JUNCTION AND TRANSITION MANHOLES

Location Manhole No. .... Designed by: ....

At .... Checked by: ....

....

Date ....

	PIPE NO.	DIAM.	GRADE (%)	CAPACITY (Q_{cap})	ACTUAL FLOW (Q_{act})
	1				
	2				
	3				
	4				

Pipe No. 1 Q_1 cap = _______ Q_1 act = _______ $\frac{Q_1 \text{ act}}{Q_1 \text{ cap}}$ = _______

From Fig. 1 read Depth of Flow = %

V_1 cap = _______ from above depth of flow and

Fig. 1 read ratio of V_1 act/V_1 cap = ______

$$\therefore V_1 \text{ act} = V_1 \text{ cap} \times \frac{\_\_\_\_\%}{100} = \_\_\_\_\_ \times \frac{\_\_\_\_\_}{100} = \_\_\_\_\_\_$$

$$H_1 = \text{pipe diameter} \times \%\ \text{depth} + \frac{(V_1 \text{ act})^2}{2g} =$$

$$\_\_\_\_\_\_\_ \times \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

Pipe No. 2 Q_2 cap = ______ Q_2 act = ______ $\frac{Q_2 \text{ act}}{Q_2 \text{ cap}}$ = _______

From Fig. 1 read Depth of Flow = %

V_2 cap = ______ from above depth of flow and
Fig. 1 read ratio of V_2 act/V_2 cap = ______

$$\therefore V_2 \text{ act} = V_2 \text{ cap} \times \frac{\_\_\_\_\%}{100} = \_\_\_\_\_\_ \times \frac{\_\_\_\_\_}{100} = \_\_\_\_\_$$

$$H_2 = \text{pipe diameter} \times \%\ \text{depth} + \frac{(V_2 \text{ act})^2}{2g} =$$

$$\_\_\_\_\_\_ \times \_\_\_\_\_\_ + \_\_\_\_\_\_ = \_\_\_\_\_\_$$

Pipe No. 3 Q_3 cap =______ Q_3 act = ______ $\frac{Q_3 \text{ act}}{Q_3 \text{ cap}}$ = ______

From Fig. 1 read Depth of Flow = %

V_3 cap = ______ from above depth of flow and
Fig. 1 read ratio of V_3 act/V_3 cap = ______

$$\therefore V_3 \text{ act} = V_3 \text{ cap} \times \frac{\underline{\hspace{1cm}}\,\%}{100} = \underline{\hspace{1cm}} \times \frac{\underline{\hspace{1cm}}}{100} = \underline{\hspace{1cm}}$$

$$H_3 = \text{pipe diameter} \times \%\text{ depth} + \frac{(V_3 \text{ act})^2}{2g} =$$

$$\underline{\hspace{1cm}} \times \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

Pipe No. 4 $Q_4 \text{ cap} = \underline{\hspace{1cm}}$ $Q_4 \text{ act} = \underline{\hspace{1cm}}$ $\frac{Q_4 \text{ act}}{Q_4 \text{ cap}} = \underline{\hspace{1cm}}$

From Fig. 1 read Depth of Flow = %

V_4 cap = $\underline{\hspace{1cm}}$ from above depth of flow and
Fig. 1 read ratio of V_4 act/V_4 cap = $\underline{\hspace{1cm}}$

$$\therefore V_4 \text{ act} = V_4 \text{ cap} \times \frac{\underline{\hspace{1cm}}\,\%}{100} = \underline{\hspace{1cm}} \times \frac{\underline{\hspace{1cm}}}{100} = \underline{\hspace{1cm}}$$

$$H_4 = \text{pipe diameter} \times \%\text{ depth} + \frac{(V_4 \text{ act})^2}{2g} =$$

$$\underline{\hspace{1cm}} \times \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

HEAD LOSS $h_e = K\frac{(V_2{}^2 - V_1{}^2)}{2g}$ for pipes 1 and 2

Select K = 0.1 or 0.2 as above

For pipes 1 and 2 $h_e = \underline{\hspace{1cm}}\ (\underline{\hspace{1cm}} - \underline{\hspace{1cm}})$
$= \underline{\hspace{1cm}}$

For pipes 1 and 3 h_e = _____ (_____ - _____)
= _____

For pipes 1 and 4 h_e = _____ (_____ - _____)
= _____

∴ for pipes 1 and 2 $h_i = (H_1 - H_2) + h_e$

h_i = _____ - _____ + _____
= _____ drop

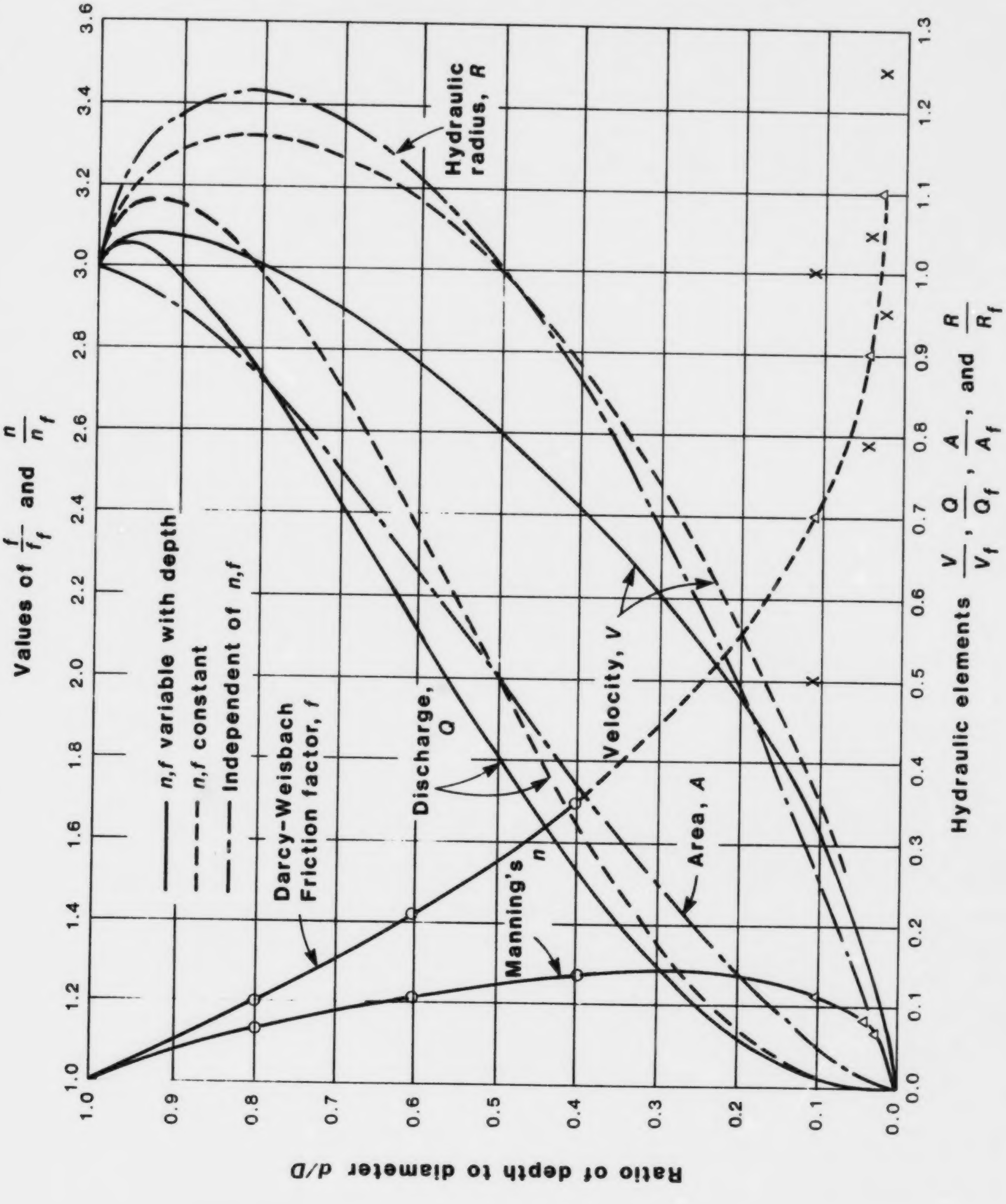
for pipes 1 and 3 h_i = _____ - _____ + _____
= _____ drop

for pipes 1 and 4 h_i = _____ = _____ + _____
= _____ drop

SUMMARY Take maximum condition of the above three cases as the governing factor which sets the required maximum drop through the manhole.

FIGURE 1

HYDRAULIC - ELEMENTS GRAPH FOR CIRCULAR SEWERS



APPENDIX E

CALCULATION OF FROST PENETRATION DEPTHS

The depths of frost penetration for areas of Ontario can be calculated using the design freezing index (degree C days) for the area of interest as shown in the following figure and using one of the following equations most closely approximating the soil conditions for the area. For design purposes, it is recommended that conditions of no snow cover be assumed.

FORMULAE FOR THE PREDICTION OF FROST DEPTH PENETRATION*

EQUATION	SOIL GROUP	
$X_1 = 0.18 + 0.044(C)^{\frac{1}{2}}$	SM	See notes on pages E-2 and E-3
$X_2 = 0.15 + 0.065(C)^{\frac{1}{2}}$	SP	
$X_3 = 0.30 + 0.050(C)^{\frac{1}{2}}$	SC	
$X_4 = 0.28 + 0.044(C)^{\frac{1}{2}}$	ML - CL	
$X_5 = 0.10 + 0.046(C)^{\frac{1}{2}}$	CH	
$X_6 = 0.074(C)^{\frac{1}{2}}$	Rock (Bare Road)	
$X_7 = -0.33 + 0.058(C)^{\frac{1}{2}}$	(all soils, except rock, where $C > 1500°$ C days)	

where

X = Frost depth penetration in metres.

C = Design Freezing index (Degree C Days).

* From references [16] and [17].

Notes Regarding Formulae X_1 Through X_5

1. Soil Groups based on "Unified System Classification of Soils for Engineering Purposes" - ASTM Designation D-2437 (except for Rock), where:

   SP - Poorly graded sands and gravelly sands, little or no fines.

   SM - Silty sands, sand-silt mixtures.

   SC - Clayey sands, sand-clay mixtures.

   ML - Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.

   CL - Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.

   CH - Inorganic clays of high plasticity, fat clays.

2. Formulae X_1 through X_5 inclusive are subject to the following assumptions/limitations:

   a) the area for which frost depth is being predicted will be kept clear of snow;
   b) the groundwater table is at a depth lower than the maximum frost penetration;
   c) the soil freezes at 0°C;

d) only one major freeze/thaw cycle occurs during a freezing season (seasonal frost area);

e) the freezing index is between 111 and 1500 freezing degree C- days;

f) data based on a region of moderate humidity, more arid regions may experience deeper penetrations;

g) predicted frost penetrations are subject to a standard error of up to .15 metres, therefore, a safety factor should be added.

3. To assist in obtaining the Design Freezing Index for any given area in the Province of Ontario the attached figure has been prepared based on temperature data collected over the period of 4 years between 1974 and 1978 by Fisheries and Environment Canada.

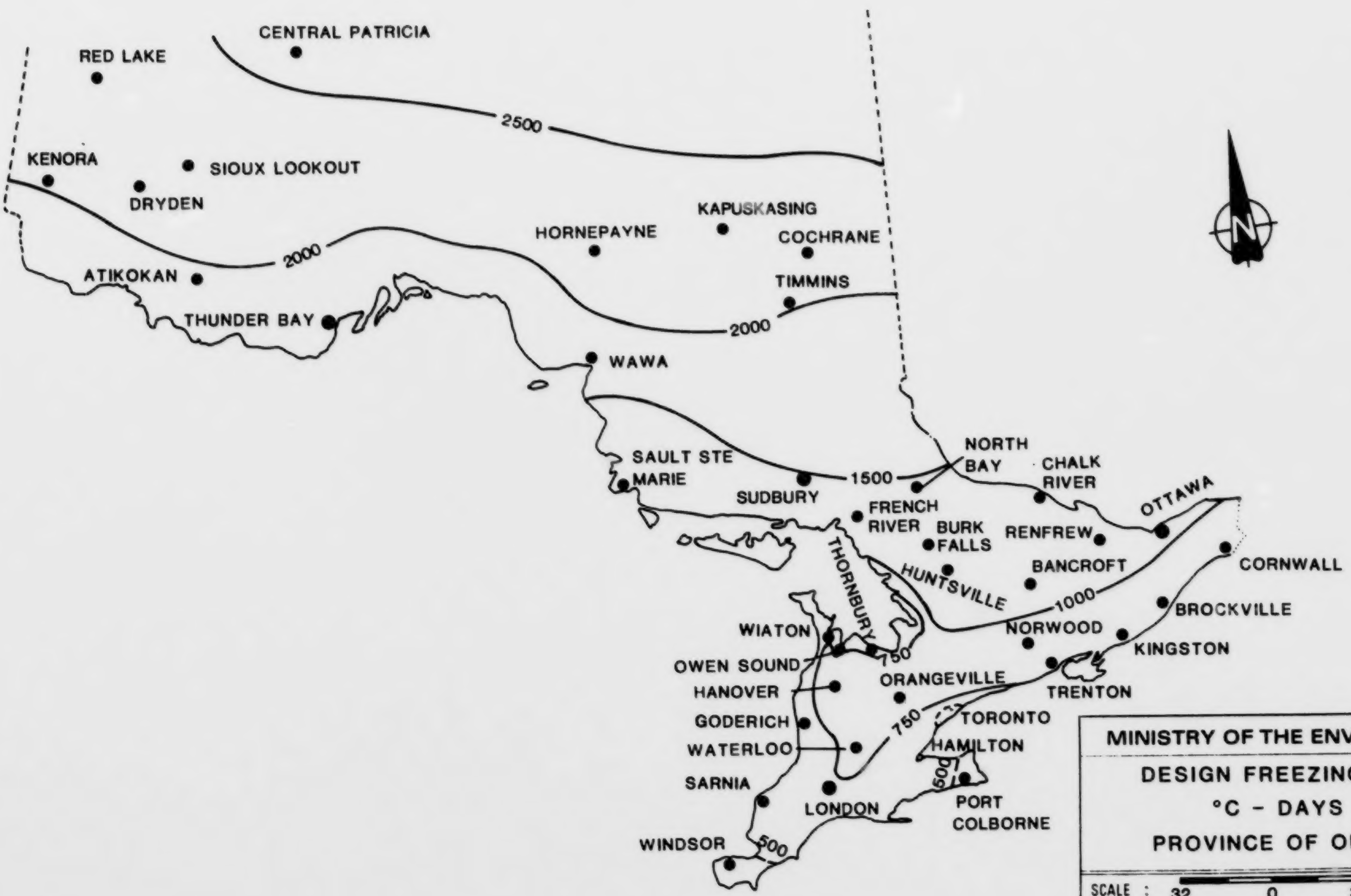
The freezing index is a measure of the severity of sub-freezing temperatures recorded in degree centigrade-days. It is computed by accumulating from day to day, during the freezing season, usually beginning about November 1st and lasting to the middle of April, the differences between 0°C and the mean daily temperature.

The Design Freezing Index based on 4 years data was computed for each chosen municipality on the basis of arithmetic probability. For example, North Bay had the following freezing indices: 1359, 1069, 1323 and 1438°C-days for the years 1974-75,/75-76,/76-77 and 77-78 respectively. From this it was calculated that there is 85% probability that the freezing index will be equal to or less than 1460°C-days (see attached table).

DESIGN FREEZING INDEX AT VARIOUS LOCATIONS IN THE PROVINCE OF ONTARIO

(85% Probability)

Atikokan	1960	Orangeville	880
Arnprior	1130	Ottawa	1040
Bancroft	1140	Owen Sound	680
Belleville	760	Port Colborne	470
Brockville	830	Red Lake	2200
Burk's Falls	1300	Renfrew	1170
Burlington	600	Ridgetown	570
Central Patricia	2600	Sarnia	600
Chalk River	1200	Sault Ste. Marie	1180
Cochrane	2170	Simcoe	640
Cornwall	870	Sioux Lookout	2210
Dryden	2050	St. Catharines	500
French River	1170	Sudbury	1480
Goderich	620	Thornbury	710
Hanover	910	Thunder Bay	1750
Hornpayne	2470	Timmins	2010
Huntsville	1090	Tobermory	730
Kapuskasing	2240	Toronto	660
Kenora	2040	Trenton	800
Kingston	800	Wawa	1630
Lansdowne	2780	Waterloo	810
London	730	Wiarton	820
North Bay	1460	Windsor	460
Norwood	900	Winisk	3510


CENTRAL PATRICIA
RED LAKE
2500
KENORA
SIOUX LOOKOUT
DRYDEN
KAPUSKASING
COCHRANE
HORNEPAYNE
2000
ATIKOKAN
TIMMINS
THUNDER BAY
2000
WAWA
N
SAULT STE MARIE
1500
SUDBURY
NORTH BAY
CHALK RIVER
OTTAWA
FRENCH RIVER
BURK FALLS
RENFREW
CORNWALL
THORNBURY
HUNTSVILLE
BANCROFT
1000
BROCKVILLE
WIATON
NORWOOD
KINGSTON
750
OWEN SOUND
ORANGEVILLE
TRENTON
HANOVER
GODERICH
TORONTO
750
WATERLOO
HAMILTON
500
SARNIA
LONDON
PORT COLBORNE
WINDSOR
500

MINISTRY OF THE ENVIRONMENT

DESIGN FREEZING INDEX

°C - DAYS

PROVINCE OF ONTARIO

SCALE : 32 0 32 64 Km

DRAWN BY : L.L.B.
DATE : FEB. 1984

CHECKED BY : B.C.
DRAWING NO. 13034

Example 1

C = 1300° C days   Soil Group - SC

$$X_3 = 0.30 + 0.050\,(C)^{\frac{1}{2}}$$

Use $X_3 = 0.30 + 0.050\,(C)^{\frac{1}{2}}$

$= 0.30 + 1.8$

$= 2.1$ m

Add Safety Factor (item g pg. E-3) 0.15 m

$\therefore$ depth of cover over watermain/service connection is
2.1 + 0.15 = 2.25 m

Example 2

C = 2500° C days   Soil Group - any soil except rock where $C > 1500°$ C days

Use $X_7 = -0.33 + 0.058\,(C)^{\frac{1}{2}}$

$= -0.33 + 2.9$

$= 2.57$ m

Add Safety Factor of 0.15 m

$\therefore$ depth of cover over watermain/service connection is
2.57 + 0.15 = 2.72 m

Say 2.75 m

Example 3

$C = 1600°$ C days   Soil Group - Rock

Use $X_6 = 0.074\ (C)^{\frac{1}{2}}$

$= 2.96$ m

Add Safety Factor of 0.15 m

$\therefore$ depth of cover over watermain/service connection is
$2.96 + 0.15 = 3.11$ m

APPENDIX F

POLICY NO. 08-02-01

STATEMENT OF POLICY TO GOVERN THE SEPARATION OF SEWERS AND WATERMAINS

1. Sewers/sewage works* and watermains located parallel to each other should be constructed in separate trenches maintaining a minimum clear horizontal separation distance of 2.5 m.

In cases where it is not practical to maintain separate trenches or the recommended horizontal separation cannot be achieved, the Ministry of the Environment or its designated "agent" may allow deviation from the above.

2.1 Rational This is considered a good engineering and construction practice and will reduce the potential for health hazard in the event of the occurrence of conditions conducive to possible contaminated ground water flow into the water distribution system.

---

*Sewers/Sewage works includes sanitary sewers, sanitary forcemains, storm sewers, and storm forcemains, and all appurtenances/fittings thereto.

JULY 1984

2.2 Contaminated ground and surface water may enter the water distribution system at leaks or breaks in piping, vacuum air relief valves, blowoffs, fire hydrants, meter sets, outlets, etc. with the occurrence of a negative internal or positive external pressure condition. Water pressure in a part of the system may be reduced to a potentially hazardous level due to shutdowns in the system, main breaks, heavy fire demand, high water usage, pumping, storage, or transmission deficiency.

2.3 It is recognized by the Ministry of the Environment that health hazards may develop through relative locations of watermains and sewers. Adequate protection must be provided to prevent the occurrence of waterborne disease and chemical poisoning due to contaminated ground water and surface runoff entering the water distribution system.

3. Exceptions Under unusual conditions, deviations from the "separate trench" requirement may be allowed but only in accordance with the Ministry of the Environment guidelines for location of sewers and watermains set out as follows.

Guidelines to Govern the Separation of Sewers and Watermains

1. GENERAL

Par 1 Ground or surface water may enter an opening in the water distribution system with the occurrence of a negative internal/positive external pressure condition. Ground water may enter the distribution system at leaks or breaks in piping, vacuum-air relief valves, blow-offs, fire hydrants, meter sets, outlets, etc. Water pressure in a part of the system may be reduced to a potentially hazardous level due to shut downs in the system, main breaks, heavy fire demand, high water usage, pumping, storage, or transmission deficiency.

Par 2 The relative location of sewers and watermains (including appurtenances) and types of material used for each system are important considerations in designing a system to minimize the possibility of contaminants entering the water distribution system.

Par 3 The use of, and adherence to, good engineering and construction practice will reduce the potential for health hazard in the event of the occurrence of conditions conducive to ground water flow into the water distribution system.

2. PARALLEL INSTALLATIONS

Par 1 1. Under normal conditions, watermains should be laid with at least 2.5 metres horizontal separation from any sewer or sewer manhole; the distance shall be measured from the nearest edges.

a) Under unusual conditions, where a significant portion of the construction will be in rock, or where it is anticipated that severe dewatering problems will occur or where congestion with other utilities will prevent a clear horizontal separation of 2.5 metres, a watermain may be laid closer to a sewer, provided that the elevation of the crown of the sewer is at least 0.5 metres below the invert of the watermain. Such separation shall be of in-situ material or compacted backfill.

b) Where this vertical separation cannot be obtained, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested, in accordance Division 701 of the OPSS at a presssure of 350 kPa, with no leakage.

c) In rock trenches, facilities should be provided to permit drainage of the trench to minimize the effects of impounding of surface water and/or leakage from sewers in the trench.

3. CROSSINGS

Par 1 1. Under normal conditions, watermains shall cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.

Par 2 2. When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected by providing:

a) A vertical separation of at least 0.5 metres between the invert of the sewer and the crown of the watermain.

b) Adequate structural support for the sewers to prevent excessive deflection of joints and settling.

c) That the length of water pipe shall be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

4. SERVICE CONNECTIONS

Par 1 Wherever possible, the construction practices outlined in this guideline should apply with respect to sewer and water services.

5. TUNNEL CONSTRUCTION

Par 1 If the "Tunnel" is of sufficient size to permit a man to enter the tunnel for the purposes of maintenance, etc., it is permissible to place the sewer and watermain through the tunnel providing the watermain is hung above the sewer.

Par 2 If the tunnel is sized only to carry the pipes, or if the tunnel is subject to flooding, the sewer shall be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested, in Division 701 of the OPSS at a pressure of 350 kPa with no leakage.

6. DESIGN FACTORS

Par 1 When local conditions do not permit the desired spacing, or water and sewer lines or other conditions indicate that detailed investigations are warranted, the following factors should be considered in the design of the environment and relative location of water and sewer lines.

Par 2 This list of factors should be considered as a guide and not all inclusive.

a) Materials, types of joints and identification for water and sewage pipes;
b) Soil conditions, e.g. in-situ soil and backfilling materials and compaction techniques;
c) Service and branch connections into the watermain and sewer lines;
d) Compensating variations in the horizontal and vertical separations;
e) Space for repair and alterations of water and sewer pipes;
f) Off-setting of pipes around manholes;
g) Location of ground-water table and trench drainage techniques;
h) Other sanitary facilities such as septic tanks and tile fields, etc.

7. VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

Par 1

a) Chambers or pits containing valves, blow-offs, meters or other such appurtenances to a water distribution system shall not be connected directly to any sanitary sewer, but may be connected to storm sewers provided that some means of back flow prevention is included.

b) Blow-offs or air relief valves shall not be connected directly to any sewer.

c) Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water; to absorption pits underground or to a sump within the chamber where ground water level is above the chamber floor.

8. POTABLE WATER RESERVOIRS BELOW NORMAL GROUND SURFACE AND WELL SUPPLIES

Par 1

Sewers, drains, and similar sources of contamination should be kept at least 15 m from potable water reserviors below normal ground surface and well supplies. Mechanical-jointed water pipes, pressure tested, in accordance with Division 701 of the OPSS at a pressure of 350 kPa with no leakage, may be used for gravity sewers at lesser separations.

9. UNACCEPTABLE INSTALLATIONS

Par 1 No watermain or service line shall pass through or come into contact with any part of a sewer, sewer manhole and/or septic tank and tile field or similar sources of contamination.

APPENDIX G

MINISTRY OF THE ENVIRONMENT

POLICY AND GUIDELINES TO GOVERN THE USE OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

A. POLICY
B. GUIDELINES

JULY 1984

A. POLICY TO GOVERN THE USE OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

Par 1 The ministry will allow the use of plastic pipe for buried, gravity-flow sewer installations.

Par 2 Plastic pipe for use in such installations will be selected using the modified Spangler equation for flexible pipe

$$x = \frac{D.K.W_c}{0.149\ F/\Delta Y + 0.061\ E'}$$

Reference: ASTM D2412

Par 3 In the absence of conclusive evidence of local conditions to the contrary, a bedding factor (K) of 0.110 and a soil modulus (E') of 1500 kPa shall be used for calculation of pipe deflection.

Par 4 In any plastic sewer pipe installation the Contractor shall be required to pass through the pipe an approved device* to demonstrate that the pipe deflection does not exceed (0.15 DR % of the Base Inside Diameter of the pipe as defined in the CSA Standard to which the pipe is made. The device shall be pulled manually through the pipe not sooner than 24 hours after the completion of backfilling. Failure of this test renders the installation unacceptable.

---

*See Notes on Page G-4.

B. GUIDELINES FOR THE DESIGN AND INSTALLATION OF PLASTIC PIPE FOR BURIED, GRAVITY-FLOW SEWERS

Par 1 In view of the large variety of plastic pipes available, the Ministry of the Environment has chosen not to classify the detailed engineering specifications (e.g., pipe connections practice, fittings and gaskets requirements, trenching and bedding condition, etc.) for individual types of plastic pipes; instead the design of the sewer system, including the selection of pipe class, must be carried out in accordance with recognized and accepted engineering practice and the recommendations of the pipe manufacturer. It is understood that design calculations may be checked by the Ministry.

Par 2 In addition, the following specific guidelines shall be adhered to:

1. Sewer system shall be designed on the basis of a Friction of $n=0.013$ for the Manning formula.

2. Pipe with $F/\Delta Y$ less than 180N/m.mm shall not be used.

3. Deflection lag factor (D) of 1.5 shall be used.

4. The minimum size for laterals connecting the street sewers to sewers on private property shall be NPS-4.

5. Laterals shall be designed for worst conditions, i.e., E' = 1500 kPa, K=0.110.

6. The manufacturer shall supply to its customers, as required, plastic specials and fittings compatible with the straight plastic pipe supplied and conforming to the design requirements for the said pipe. Tees for service connections shall be available to permit connection to other generally accepted pipe materials such as concrete, asbestos cement and vitrified clay.

7. Installation of pipe shall conform to accepted engineering practice and manufacturer's recommendations. The installation shall be closely inspected.

8. For Ministry managed projects, the Ministry may issue to the consulting engineer more specific requirements, supplementary to the foregoing, including provisions to be incorporated in the contract specifications.

NOTES:

(i) The "approved device" shall be cylindrical in shape and constructed with nine or more evenly spaced arms or prongs. Mandrels with fewer arms will be rejected as not sufficiently accurate. The minimum diameter (not nominal diameter) of a circle scribed around the outside of the mandrel arms shall be equal to the allowable computed deflected "diameter" minus 1.0 mm.

The radius of the circle scribed around the outside of the mandrel arms can be determined using the following equation.

$$r = \frac{2b\,(1 + \cos\frac{\alpha}{2})}{(1 - \cos\frac{\alpha}{2})^2 + \frac{(b^2.\sin^2\frac{\alpha}{2})}{a^2}}$$

where r = radius to the outside of the mandrel arms
a = major axis of deformed/deflected pipe, assuming an elliptical shape
b = minor axis of deformed/deflected pipe, assuming an elliptical pipe
α = angle subtended between the mandrel arms.

(ii) Allowances for pipe wall thickness tolerances or ovality shall not be deducted from the allowable minimum diameter but shall be counted in as part of the maximum allowable deflection.

(iii) The mandrel shall be hand-pulled by the contractor through all sewer lines. Any sections of sewer not passing the mandrel shall be uncovered and the contractor shall repair or replace the pipe to the satisfaction of the engineer. The repaired sections shall be retested.

(iv) The contact length (L) of the mandrel shall be measured between the points of contact on the mandrel arm. This length shall not be less than that shown in the following table. It is advisable not to exceed the L dimension shown, otherwise insertion of the mandrel into the pipe may be difficult because of channel constrictions in the manhole.

Nominal Pipe Size (NPS)	L(mm)
6	100
8	150
10	200
12	250
14	300
15	300
16	300
18	350
20	400
21	450
24	500
27	575

(v) The engineer shall be responsible for determining the acceptability of the mandrel. Go/No-Go Proving rings shall be used to assist in this acceptance.

The Go/No-Go proving rings shall have a diameter equal to twice the radius of the circle scribed around the outside of the mandrel arms (see i) above ± 0.1 mm. An acceptable mandrel shall not pass through this proving ring. The proving ring shall be fabricated from minimum 6mm thick steel

APPENDIX "H"

MINISTRY OF THE ENVIRONMENT

ENVIRONMENTAL APPROVALS

AND

PROJECT ENGINEERING BRANCH

SEWAGE PUMPING STATION DESIGN - TABLE I

MUNICIPALITY ______________ PROJECT No. __________

PUMPING STATION No. OR NAME : ______________________

DESIGNED BY ______________ DATE __________

DESIGN SUBJECT	UNIT	INITIAL PERIOD	10 YEARS PERIOD	20 YEARS PERIOD	ULTIMATE PERIOD
TRIBUTARY AREA A) RESIDENTIAL B) COMMERCIAL C) INDUSTRIAL	ha				
POPULATION DENSITY	PERS/ha				
POPULATION OR EQUIVALENT A) RESIDENTIAL B) COMMERCIAL C) INDUSTRIAL	NO.				
PER CAPITA FLOW	L/cap.d				
AVERAGE FLOW	L/s				
PEAK FLOW FACTOR	$1 + \frac{14}{4+\sqrt{P}}$				
PEAK DOMESTIC FLOW	L/s				
INFILTRATION RATE	L/ha.s				
INFILTRATION	L/s				
DESIGN PEAK FLOW	L/s				
PUMPS	NO.				
PUMP DISCHARGE	L/s				
FORCE MAIN DIAM.	NPS				
VELOCITY	m/s				

MINISTRY OF THE ENVIRONMENT
ENVIRONMENTAL APPROVALS
AND
PROJECT ENGINEERING BRANCH

SEWAGE PUMPING STATION DESIGN - TABLE II

MUNICIPALITY _ _ _ _ _ _ _ PROJECT No. _ _ _ _ _

PUMPING STATION No. OR NAME : _ _ _ _ _ _ _ _ _ _ _ _ _ _

DESIGNED BY _ _ _ _ _ _ _ _ _ _ _ _ _ DATE _ _ _ _ _ _ _ _ _

	FLOW L/s	F. MAIN DIAM	VEL. m/s	H.L. m/ 100m	DIST. m	H.L. m	FITT. H.L.m	P.S. H.L.m	TOT. H.L.m	L.W.L. W/WELL	H.W.L. W/WELL	F.MAIN END EL.	STATIC HEAD		TOT.DYN HEAD	
													MAX.	MIN.	MAX.	MIN.
C = 120																
C = 140																

APPENDIX I

INFORMATION REQUIRED FOR PUMPING STATIONS APPLICATIONS

In order to assess the need for standby power at pumping stations, it is necessary to know details of the power supply, the receiving watercourse and the pumping station. Complete the following questionnaire and submit it along with the application for approval.

II A. ELECTRICAL POWER SUPPLY

(i) The name of the operating authority of the power system at the point where the pumping station is tied in is ____________ ____.

(ii) The number of power feeder lines supplying the grid operated by this authority is ____.

(iii) The number of alternate routes possible within the power grid to supply the point of connection is ________________________.

(iv) The number of alternate transformers through which power could be directed to power the pumping station in the event of failure of the major feed is _____________ ____.

(v) Is the service above ground?____________.

(vi) List the power abnormalities including power surges and drops during the past 5 years for the area of the pumping station.

Date	Duration	Reason for Abnormality

II B. RECEIVING WATERCOURSE

(i) It will be necessary to know in detail the route by which by-passed flow would gain access to any receiving watercourse. A detailed description of the flow path that would be taken and a sketch showing the route should be provided as well as the following information.

(ii) The flow in the receiving watercourse at the point of by-pass from the pumping station is as follows:

- FLOW IN DRY WEATHER ___________ m^3/s
- FLOW IN WET WEATHER ___________ m^3/s

(iii) The nearest water intake is located on the receiving watercourse within ______ metres of the point of entry of the by-passed flow.

(iv) A summary of the domestic water works on the receiver within the sphere of influence of the by-pass point would include

Name of Water Works	Approximate Distance from point of by-pass

II C. PUMPING STATION

(i) The operating authority responsible for maintenance and operation of this pumping station is ______________________________.

(ii) The high level alarm is set up to relay a signal to ______________________________.

(iii) Between the time of activation of the high level alarm and the by-passing of sanitary sewage there are

______________ m^3 of storage capacity available in the sewers

______________ m^3 of storage capacity available in the pumping station

(iv) This storage will provide

_____________ minutes retention before by-pass at the average daily design flow of ______ L/s.

_____________ minutes retention before by-pass at the peak design flow of ______ L/s.

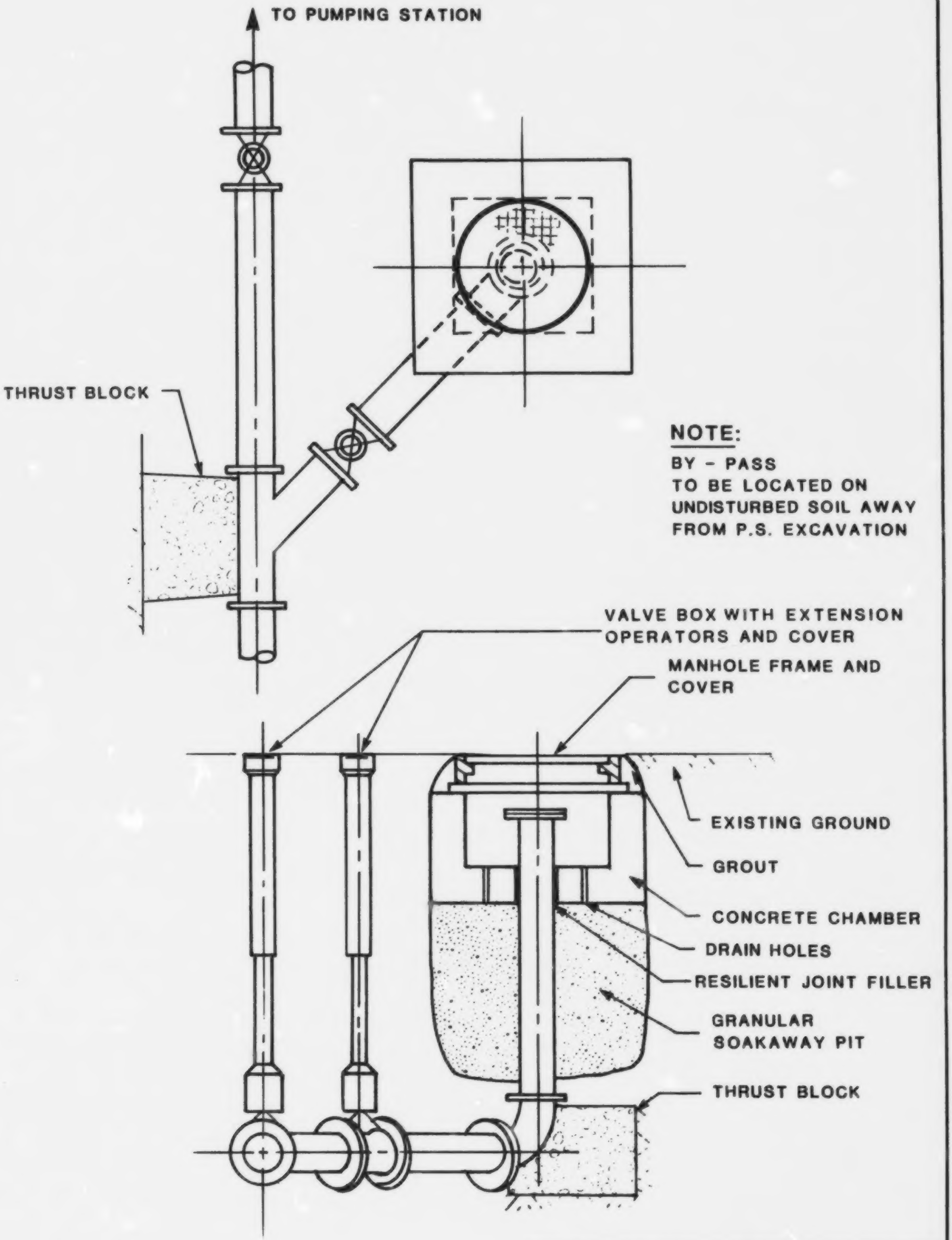
(v) The pumping station control ___________ ("is" or "is not") equipped to automatically re-start pumps in the event of their shutting down during power fluctuations and outages.

(vi) It is possible to pump around the pumping station with portable equipment by utilizing the following procedure ________

____

____

_______________________________________.


TO PUMPING STATION
THRUST BLOCK
VALVE BOX WITH EXTENSION OPERATORS AND COVER
MANHOLE FRAME AND COVER
EXISTING GROUND
GROUT
CONCRETE CHAMBER
DRAIN HOLES
RESILIENT JOINT FILLER
GRANULAR SOAKAWAY PIT
THRUST BLOCK

NOTE:

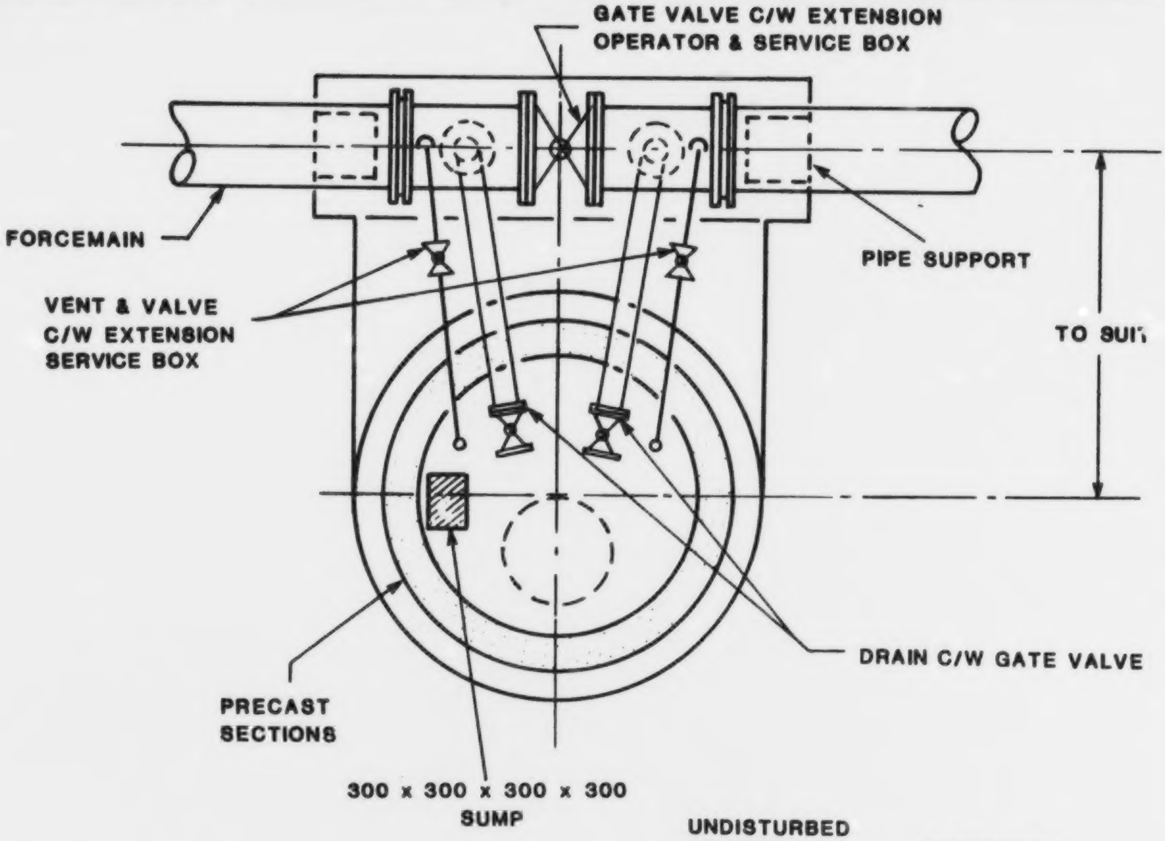
BY - PASS
TO BE LOCATED ON
UNDISTURBED SOIL AWAY
FROM P.S. EXCAVATION

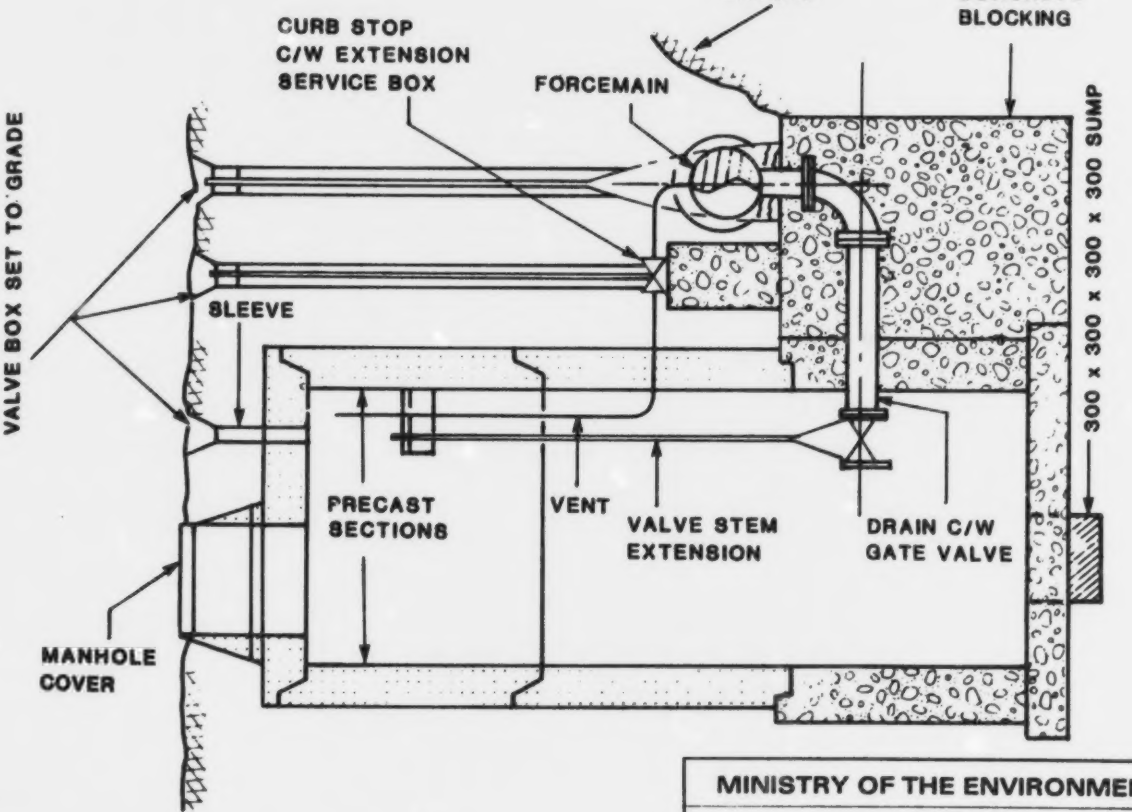
MINISTRY OF THE ENVIRONMENT

APPENDIX "J"
TYPICAL SEWAGE STATION
FORCEMAIN
BY-PASS CONNECTION

SCALE : Note to Scale

DRAWN BY : L.L.B.	DATE : FEB. 1984
CHECKED BY : B.C.	DRAWING NO. 13036


GATE VALVE C/W EXTENSION
OPERATOR & SERVICE BOX
FORCEMAIN
PIPE SUPPORT
VENT & VALVE
C/W EXTENSION
SERVICE BOX
TO SUI
DRAIN C/W GATE VALVE
PRECAST
SECTIONS
300 x 300 x 300 x 300
SUMP


UNDISTURBED
GROUND
CONCRETE
BLOCKING
CURB STOP
C/W EXTENSION
SERVICE BOX
FORCEMAIN
300 x 300 x 300 x 300 SUMP
VALVE BOX SET TO GRADE
SLEEVE
PRECAST
SECTIONS
VENT
VALVE STEM
EXTENSION
DRAIN C/W
GATE VALVE
MANHOLE
COVER

MINISTRY OF THE ENVIRONMENT

APPENDIX "K"

TYPICAL FORCEMAIN LINE VALVE/
DRAIN VALVE CHAMBER

SCALE : Not to Scale

DRAWN BY : L.L.B.
DATE : FEB. 1984

CHECKED BY : B.C.
DRAWING NO. 13036

APPENDIX L

Peaking Factors for Municipal[1] Water Supply Systems

POPULATION RANGE	MINIMUM RATE FACTOR[2] (MIN. HOUR)	MAXIMUM DAY FACTOR[3]	PEAK RATE FACTOR[4] (MAX. HOUR)
500 - 1 000	0.40	2.75	4.13
1 001 - 2 000	0.45	2.50	3.75
2 001 - 3 000	0.45	2.25	3.38
3 001 - 10 000	0.50	2.00	3.00
10 001 - 25 000	0.60	1.90	2.85
25 001 - 50 000	0.65	1.80	2.70
50 001 - 75 000	0.65	1.75	2.62
75 001 -150 000	0.70	1.65	2.48
greater than 150 000	0.80	1.50	2.25

Example: Assume a) Projected 20-year population of Town is 3,600 persons

b) Average per capita water consumption is 0.3 m^3/cap.d

Calculate a) Average day

b) Minimum rate

c) Maximum day

d) Peak rate

Solution a) Average day = 3600 x 0.3 = 1080 m^3/d

b) Minimum rate = 1080 x 0.5 = 540 m^3/d

c) Maximum day = 1080 x 2.00 = 2160 m^3/d

d) Peak rate = 1080 x 3.00 = 3240 m^3/d

Notes:

1 These peaking factors are suitable for use with an entire municipal system with its variety of water uses (residential, industrial and commercial). For portions of a municipal system such as an industrial subdivision, they may over-estimate actual peaks and under-estimate minimum rates, whereas, with a purely residential area they may under-estimate the actual peaks and over-estimate the minimum rates. For sub-areas of a municipality refer to Section 2.1.1 for a discussion of peaking factors for residential, industrial and commercial areas.

2 Minimum hourly consumptions may be estimated by multiplying the average day usage by the minimum rate factor. By definition, the minimum hour is the minimum usage rate on the maximum day.

3 Maximum day usage may be estimated by multiplying the average day usage by the maximum day factor.

4 Peak rate water usage may be estimated by multiplying the average day usage by the peak rate factor.

APPENDIX M

MINISTRY OF THE ENVIRONMENT
Policy
to Govern the Use of
PVC Pipe
for
Pressure Applications

STATEMENT OF PRINCIPLES

1. The Ministry will allow the use of PVC pipe for watermains.

2. Such pipe shall be certified as conforming to CSA Standard B137.3.

GUIDELINES FOR PVC PRESSURE PIPE

1. GENERAL REQUIREMENTS

1.1 PIPE SELECTION AND INSTALLATION

Par 1 The use of PVC pipe for water-system applications shall conform with the following requirements:

1) Working Pressure - The working pressure of the water system, as defined in Section 2.1, shall not exceed the pressure rating of pipe used as calculated according to Section 3.1.

2) Total System-Pressure - The Total System-pressure, as defined in Section 2.1, shall not exceed a corresponding pressure rating

for the pipe used that is determined in accordance with Section 3.2.

3) Installation - Pipe shall be installed underground in a manner that will ensure that external loads will not subsequently cause a decrease of more than 5 per cent in its vertical cross-section dimension.

1.2 INTERNAL PRESSURES AND EXTERNAL LOADS

Par 1 The design of pipe for internal pressures and external loads shall conform with the methods described herein.

2. DESIGN TERMINOLOGY

2.1 DEFINITIONS

Par 1 Under this guideline, the following definitions shall apply:

2.1.1 Working Pressure - The maximum anticipated sustained operating pressure of the water system.

2.1.2 Surge Pressure - The maximum pressure increase above working pressure, sometimes called water hammer, that is anticipated in the system as a result of change in the velocity of the water column when valves are operated, or pumps are started or stopped.

2.1.3 Total System-Pressure - The sum of the working pressure plus the surge pressure.

2.1.4 Hydrostatic Design Basis - The long-term, hydrostatic-strength (hoop stress) rating in kPa of a specific plastic-pipe material for water/pressure service at a particular maximum operating-temperature; as determined by hydrostatic tests and detailed evaluation procedures in accordance with ASTM D2837, A Method of Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.

2.1.5 Factor of Safety - A number used to reduce the hydrostatic design basis of a pipe material and thus establish an allowable design stress for that material (Section 3.6).

3. INTERNAL PRESSURES

3.1 PRESSURE CLASS - PIPE

Par 1 The pressure class (working-pressure rating) of PVC pipe shall be determined by using one of the following formulas:

$$PC = \left(\frac{2t}{D-t} \times \frac{HDB}{F}\right) - P_s\text{; or} \qquad (1)$$

$$PC = \left(\frac{2}{R-1} \times \frac{HDB}{F}\right) - P_s \qquad (2)$$

Where PC = Pressure class, kPa
t = Minimum wall-thickness, mm
D = Average outside-diameter, mm
HDB = Hydrostatic design basis, kPa
F = 2.0 factor of safety (Sec. 3.6)
P_s = Allowance for surge, pressure kPa (Sec. 3.3.1)
R = Dimension ratio

3.2 TOTAL PRESSURE-PIPE

Par 1 The pressure rating of PVC pipe for total system-pressure shall be determined by using one of the following formulas:

$$P = \frac{2t}{D-t} \times \frac{HDB}{F} \text{ ; or} \qquad (3)$$

$$P = \frac{2}{R-1} \times \frac{HDB}{F} \qquad (4)$$

Where P = Pressure rating for total system-pressure, kPa; and other factors are the same as in Formulas (1) and (2)

3.3 SURGE PRESSURE

Par 1 3.3.1 Surge-Pressure Allowances - An allowance for surge pressure equal to not less than that generated by an instantaneous velocity change of 0.6 m/s shall be made in all cases. Excessive surge pressures should be prevented by elimination of the causative condition or providing automatic surge-pressure relief.

Par 2 3.3.2 Pressure Rise - The wave velocity and pressure rise resulting from abrupt change in the velocity of a column of water shall be determined using the following formulas:

$$a = \frac{1420}{(1 + KD_i/Et)^{\frac{1}{2}}} \qquad (5)$$

where a = Wave velocity, m/s
K = Bulk modulus of water = 2000 MPa
D_i = Inside diameter of pipe, mm
E = Modulus of Elasticity of pipe material (for PVC, 2800 MPa)
T = Wall thickness of pipe, mm

$$\frac{KD_i}{Et} = \frac{K\ (R-2)}{E}$$

where R = Dimension ratio of pipe = Do/t
Do = Outside diameter of pipe, mm

$$Ps = \frac{9.79\ aV}{g}$$

where Ps = Pressure rise, kPA
a = Wave velocity, m/s
V = Velocity change, m/s, occurring within the critical time $2\ L/a$ where L is the length of the pipeline in metres
g = Gravitational acceleration = $9.81\ m/s^2$

3.4 HYDROSTATIC DESIGN BASIS (HDB)

Par 1 The HDB of PVC pipe (Class 12454-B and C materials) for water service at 23°C is 28 MPa. The HDB will be less than 28 MPa for pipe use at temperatures above 23°C (Sec. 3.5).

3.5 DESIGN STRESS

Par 1 The allowable design stress (HDB/F) for use of PVC pipe at 23°C and lower temperatures is 14 MPa. For pipe use at higher operating-temperatures, the allowable design stress shall be determined by use of an HDB rating recommended by the Plastic Pipe Institute for the operating temperature or by applying the appropriate temperature coefficient given in Table 3, Section 7.4, to the design stress allowed for pipe service at 23°C. The temperature coefficients are de-rating factors that may be applied also to pressure-class ratings for pipe used at temperatures above 23°C.

3.6 FACTOR OF SAFETY

Par 1 The 2.0 factor of safety specified for use in the pressure-class and total-pressure formulas is only a portion of that provided for working pressure and for total system-pressure.

Par 2 There are two pressure conditions of concern and a different factor of safety applies to each. These conditions are:

1) sustained working pressure which is a long-term hydrostatic strength (HDB) of the pipe, and
2) total system-pressure which is a short-term peak pressure condition and which relates to the short-term hydrostatic strengths of the pipe. The long-term and short-term hydrostatic strengths of PVC pipe at 23 C are respectively 14 and 44 MPa.

Par 3 A factor of safety is provided for total system-pressure. It is the ratio of 44 MPa (minimum short-term strength) to 14 MPa (allowable design-stress, HDB/2.0).

4. EXTERNAL LOADS

4.1 DEAD LOADS

Par 1 The earth load shall be determined using the Modified Iowa State Formula (1) for loads imparted to a flexible pipe, as follows:

$$W_e = C_d w B_d B_c \qquad (7)$$

where W_e = Earth load, N/lin. metre

C_d = A coefficient, based on type of backfill soil and on the ratio of H (depth of fill to top of pipe, m) to B_d. (See Figure 1)

w = Unit of weight of soil, N/m^3

B_d = Ditch width at top of pipe, m

B_c = Outside diameter of pipe, m

4.2 LIVE LOADS

Par 1 The live load (W_1) shall be determined using the modified AASHO H20 loading as given in Table 1, which is based on two passing trucks with adjacent wheels 0.9 metres apart, having a 40 320 N load on unpaved road or flexible pavement, and which includes 50 per cent impact.

TABLE 1

Highway Live Loads*

Normal Pipe Size (NPS)	Depth of Cover, metres							
	0.76	1.06	1.52	2.44	3.66	4.88	6.10	7.31
	W_1 - N/m							
4	4,333	2,364	1,182	788	584	394	263	204
6	8,272	4,727	2,758	1,371	992	584	379	292
8	11,424	7,091	4,333	2,159	1,371	788	525	409
10	14,240	9,060	5,515	2,758	1,576	992	657	511
12	16,939	11,030	6,697	3,545	1,780	1,182	773	598

4.3 TOTAL LOAD

Par 1 The total load (W) on buried flexible pipe is as follows:

$$W = W_e + W_1, \text{ N/lin. metre} \qquad (8)$$

5. DEFLECTION

5.1 GENERAL

Par 1 The stresses that result from internal pressure and external load are not additive in the design of a flexible conduit such as PVC pipe. Although a maximum deflection of 5 per cent is specified in 1.1.3, PVC pipe can be deflected up to 10 per cent without reducing its ability to resist internal pressure. Failure modes are discussed in Section 7.

5.2 DESIGN THEORY - EARTH LOADS

Par 1 The best documented and best known design theory for the deflection of a cylindrical horizontal tube under earth load is Spangler's (2,3) Modified Formula for the deflection of a buried unpressurized tube. The formula for PVC pipe is as follows:

$$Y_v = \frac{De\ KWe}{2E/3(R-1)^3+0.061E'} \tag{9}$$

Where Y_v = Vertical deflection of pipe, m

D_e = Deflection lag factor (for plastic, 1.5)

K = Bedding constant (See Table 2, Sec. 5.4)

W_e = Earth load on pipe (N/lin metre)

R = Dimension ratio

E = Modulus of Elasticity of pipe material (for PVC, 2.76×10^9 Pa)

E' = Modulus of Soil Reaction (See Table 2)

5.3 EARTH LOAD PLUS LIVE LOAD

Par 1 For inclusion of live loads, Spangler's Formula must be further modified since the deflection lag factor is not applicable to live loads. The formula is as follows:

$$Y_v = \frac{D_e K W_e + K W_l}{2E/3(R-1)^3 + 0.061E'} \qquad (10)$$

Where W_l = Live load on pipe (N/lin metre) and other factors are the same as in Formula (9).

5.4 DEFLECTION FORMULA FACTORS - D_e, K and E'

Par 1 The values for D_e, K and E' corresponding to different pipe-embedment conditions for use in Formulas (9) and (10) are given below in Table 2.

TABLE 2

Embedment(a) Class	De	Bedding Angle	K	E',Pa
Class B	1.50	120°	0.090	4.8×10^6(b)
Class C	1.50	60°	0.102	2.8×10^6(b)
Class D	1.50	0°	0.110	1.0×10^6(b)

(a) As described in ASCE Manual No. 37 (WPCF Manual No. 9)(6).

Note: Granular bedding material, as defined in these manuals, is specified for Embedment Classes B and C.

(b) If the sidefill material is compacted to 85 per cent Standard Proctor Density, the value of E' can be raised to 6.9×10^6 for Class B and to 4.8×10^6 for Class C.

6. INSTALLATION

6.1 PIPE EMBEDMENT

Par 1 The embedment of pipe shall conform with Class B, C or D, as detailed in ASCE Manual No. 37(6); or with the recommended practices given in ASTM D2321(7). A flexible pipe, unlike a rigid pipe, tends to bed itself. For flexible pipe, the most important parameters are stability of the bedding and density of the sidefills. Installation precautions are given also in ASTM D2321(7).

7. FAILURE MODES

7.1 GENERAL

Par 1 Flexible conduits can fail by buckling or collapse due to excessive external load, a negative or vacuum pressure, excessive bending stresses in the walls, excessive deflection, or a combination of these forces. Plastic conduits can also fail by reduction of ring stiffness (strength) due to excessive temperature of the fluid being transported or of the environment in which they are installed.

7.2 BUCKLING

Par 1 Experiments at the Utah State University now being conducted by Dr. Reynold Watkins (unpublished to date) indicate that plastic pipe does not fail by buckling in the same mode as steel pipe. Steel pipe dimples in, the dimple reverses curvature, and then folds in on the lower portion. Steel follows Timoshenki's formula in AWWA M11(4) in a free environment, but the formula must be modified if the pipe is confined in an earth envelope. Plastic pipe, however, tends to deform (flatten) during vertical deflection and then fold in upon the lower portion. Therefore, if deflection is controlled, buckling will not occur under normal embedment conditions.

7.3 NEGATIVE OR VACUUM PRESSURE

Par 1 According to Dr. Watkin's experiments, negative or vacuum pressures cannot collapse an underground plastic pipe that is properly encased in a soil envelope and exposed to normal service temperatures. However, if the temperature of a plastic pipe is excessive due to temperature of fluids conveyed or exposure to sunlight, application of a negative pressure can cause pipe collapse.

7.4 EXCESSIVE TEMPERATURE

Par 1 If PVC pipe is used to convey fluids of excessive temperature or is installed in an environment where excessive temperatures can influence the conduit, the allowable design stress should be appropriately reduced according to the following Table 3: or for operating temperatures that do not exceed 90°F, pipe of a pressure class next higher to that required for service at 73°F may be used.

TABLE 3

TEMPERATURE COEFFICIENTS

Maximum Service Temperature °C	Per cent of the Allowable Design Stress or Pressure Class Rating at 23°F
27	88
32	75
38	62
43	50
49	40
54	30
60	22

7.5 BENDING STRESSES IN WALLS

Par 1 Plastic pipe embedded in soil acts similar to steel pipe and tends to bed itself and thereby re-adjusting wall stresses. The pipe will not fail from excessive wall stresses if deflection is controlled by proper installation.

8.1 PIPE DIMENSIONS

Par 1 Pipe manufactured to Cast Iron Pipe Size dimensions will be considered an acceptable alternative if it meets the requirements of CSA Standard B137.3 in all other respects.

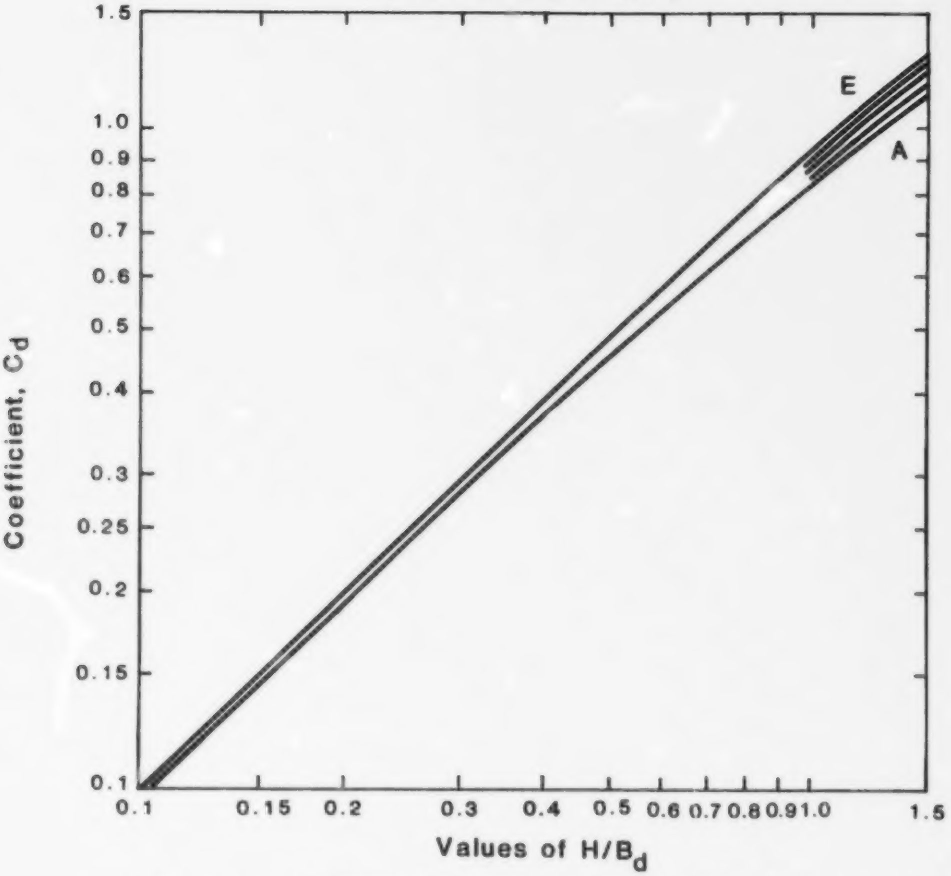


FIG. A.1a : COMPUTATION DIAGRAM FOR EARTH LOADS ON TRENCH CONDUITS (CONDUITS BURIED IN TRENCHES)

A = C_d FOR Ku AND Ku' = 0.1924 FOR GRANULAR MATERIAL WITHOUT COHESION

B = C_d FOR Ku AND Ku' = 0.165 MAXIMUM FOR SAND AND GRAVEL

C = C_d FOR Ku AND Ku' = 0.150 MAXIMUM FOR SATURATED TOPSOIL

D = C_d FOR Ku AND Ku' = 0.130 ORDINARY MAXIMUM FOR CLAY

E = C_d FOR Ku AND Ku' = 0.110 MAXIMUM FOR SATURATED CLAY

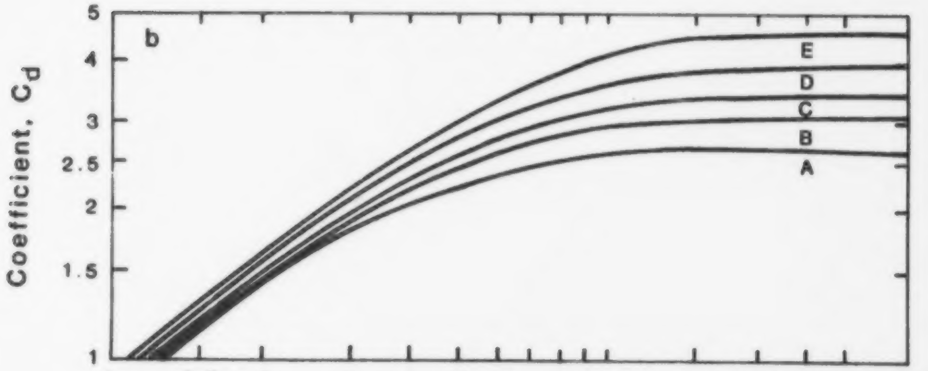


FIG. A.1b : EXPANDED SCALE OF COMPUTATION DIAGRAM FOR EARTH LOADS ON TRENCH CONDUITS

APPENDIX N

Design Criteria
for
Sizing Water Storage Facilities

TOTAL STORAGE REQUIREMENT = A + B + C

Where A = Fire Storage
B = Equalization Storage
(25% maximum day demand)
C = Emergency Storage (25% of A + B)

Par 1 The above equation is for the calculation of the storage requirement for a system where the water treatment plant is capable of satisfying only the maximum day demand. For situations where the water treatment plant can supply more, the above storage requirements can be reduced accordingly.

Par 2 The maximum day demand referred to in the foregoing equation should be calculated using the factors in the following Table 1, unless there is existing flow data available to support the use of different factors. Where existing data is available, the required storage should be calculated on the basis or a careful evaluation of the flow characteristics within the system.

Par 3 Should the proponent have elected to provide a potable water supply and distribution system not capable of providing fire protection, the usable volume of storage to be provided should be 25% of the design year maximum day plus 40% of the design year average day.

Par 4 When determining the fire flow allowance for commercial or industrial areas, it is recommended that the area occupied by the commercial/industrial complex be considered at an equivalent population density to the surrounding residential lands. Alternatively, when very large or high fire load buildings are present/probable or large area or high hazard industrial or commercial buildings are present/probable, the municipality should strongly encourage the installation of an approved automatic sprinkler system and alarm supervisory service. Such an installation can result in substantial reductions to the required fire flows and hence, the sizing of the communal water supply, distribution and storage facilities. Specific details in this regard can be obtained from either the Office of the Fire Marshall or the Insurers Advisory Organization - Fire Underwriters Survey.

Par 5 When an entirely new water supply and distribution system is being designed this guide should be used in conjunction with Guidelines for the Design of Water Distribution Systems.

TABLE 1

Equivalent Population	Maximum Day Factor	Peak Rate Factor (Peak Hr)
500 - 1 000	2.75	4.13
1 001 - 2 000	2.50	3.75
2 001 - 3 000	2.25	3.38
3 001 - 10 000	2.00	3.00
10 001 - 25 000	1.90	2.85
25 001 - 50 000	1.80	2.70
50 001 - 75 000	1.75	2.62
75 001 -150 000	1.65	2.48
greater than 150 000	1.50	2.25

Maximum Day Demand =

Average Day Demand x Maximum Day Factor

TABLE 2

FIRE FLOW REQUIREMENTS

Equivalent Population	Suggested Fire Flow L/s	Duration (hours)
500 - 1 000	38	2
1 000	64	2
1 500	79	2
2 000	95	2
3 000	110	2
4 000	125	2
5 000	144	2
6 000	159	3
10 000	189	3
13 000	220	3
17 000	250	4
27 000	318	5
33 000	348	5
40 000	378	6

NOTES

1. For intermediate populations design values should be determined by interpolation.

2. For equivalent population, reference Par 4 on page N-2.

APPENDIX O

FROST LOADING ON BURIED CONDUITS

Studies undertaken respecting frost-induced loads on buried conduits (9,10,15,16) have shown that frost can increase the external load on the pipe by as much as 200%. A failure to recognize this phenomenon and allow for the same in the design of pipe installations in areas subject to frost could result in increased capital and operating costs associated with the repair of damaged conduits. With this in mind, it is suggested that the design of buried conduits (i.e., sewers, watermains, forcemains, etc.) take into consideration the increased loads due to frost. This may require that a stronger class of pipe material be used and/or a higher class of bedding be specified. Care should also be taken to ensure the proper installation of the pipe bedding specified.

APPENDIX P

PREVENTION OF FROST HEAVE IN PRE-CAST MANHOLES & CHAMBERS

In areas where the freezing index is greater than 500 freezing degree (C)-days, precast manholes/chambers should have three (3) steel straps extending vertically from top to bottom and held by bolts in the top and bottom sections.

The bolt distance from joint (h) in metres may be determined by:

$$h \geq (F_{si}/F_{ss}).(\pi/n).(r + t)/(2t).H$$

in which

F_{si} = shear stress of interface (80 to 125 kPa)

F_{ss} = shear stress of concrete (1400 kPa)

H = frost depth in metres

r = manhole internal radius in metres

t = manhole wall thickness in metres

The three (3) steel straps should be located at points equidistant around the circumference of the manhole/ chamber.

When the design freezing index equals or exceeds 1800 freezing degree (C)-days, an additional granular water draining layer at least 0.3 m thick should surround the manhole.

REVISED JULY 1985

APPENDIX Q
THERMAL CONSIDERATIONS

In regions where cold temperatures are prevalent, such as in Northern Ontario, it is just as, if not more, important to carry out a thermal analysis as it is a hydraulic analysis of any proposed service system. This is necessary to prevent frost damage to the system.

Freeze Protection

The solution to pipe freezing stated simply is to reduce or replace heat losses. Heat losses are replaced by removing the cooled water before it freezes and replacing it with warmer water, heating the water in the pipe, or heating the pipe itself. Heat losses are reduced mainly by the use of some form of insulation.

In order to determine the amount of heat that needs to be replaced or the amount of insulation that is required, it will first be necessary to calculate the heat losses that will occur.

Thermal Analysis - Design Formulae and Calculations

Although thermal calculations require the use of nonsteady state equations, some steady state formulae have been generated to approximate some of the variables that need to be considered. Engineering experience and judgement are important factors in any thermal analysis.

Figures Q-1 through Q-7 and Tables Q-1, 2 & 3, have been reproduced from the "Cold Climate Utilities Delivery Design Manual, Environment Canada". With the proper use of these tables and figures, it will be possible to obtain fair approximations of the required actual values. The following examples have been included to illustrate the use of some of the formulae presented.

EXAMPLE THERMAL CALCULATIONS

Example 1

Calculate the rate of heat loss (per unit length) from a plastic pipe of outside diameter of 166 mm and inside diameter of 136 mm whose thermal conductivity is 0.36 W/m·K and is encased in 50 mm of polyurethane foam of thermal conductivity of 0.023 W/m·K that is buried at a depth of 1.22 m in a soil with a thermal conductivity of 2.0 W/m·K when the fluid temperature is 5°C and the (steady state) ground surface temperature is -40°C.

Solution: (From Equations in Figure Q-1(b))

For Insulation

$r_I = (166 + 100) \div 2 = 133, \; r_p = 166/2 = 83$

$K_I = 0.023 \text{ W/m·K}$

$$R_I = \frac{\ln (r_I/r_p)}{2\pi K_I} = \frac{\ln (133/83)}{2\pi (0.023)} = 3.26 \text{ m·k/W}$$

For Pipe

$r_I = 166/2 = 83, \; r_p = 136/2 = 68$

$K_p = 0.36 \text{ W/m·K}$

$$R_p = \frac{\ln (83/68)}{2\pi (0.36)} = 0.09 \text{ m·K/W}$$

For Soils

$k_s = 2.0 \text{ W/m·k}$

$H_p/r_p = 1.22/0.083 = 14.7$

since $H_p \geq 2\, r_p$ then

$$R_s = \frac{\ln (2\, H_P/r_p)}{2\pi K_s} = \frac{\ln (2.1.22/0.083)}{2\pi (2)}$$

$$= 0.27 \text{ m·K/W}$$

$$R_C = R_I + R_p + R_s = 3.26 + 0.09 + 0.27$$
$$= 3.62 \text{ m·K/W}$$

Rate of Heat Loss

$$Q = (T_W - T_A)/R_C = \frac{5 - (-40)}{3.62} = 12.43 \text{ W/m}$$

Example 2

Calculate the Design Freeze-up Time, the Safety Factor Time and the Complete Freezing Time for the pipe design used in Example 1 if the water ceases to flow. Assume $T_A = -15°C$

Solution:

r_w = 0.068 m, $T_W = 5°C$, $T_A = -15°C$
R_C = 3.62 m·K/W = 3.62 s·m·K/J

For Water: $\gamma = 1000\ Kg/m^3$, L = 80 cal/g = 334,720 J/Kg
Cp = 1 cal/g·K = 4,184 J/Kg·K

Design Time:

$$t_D = \pi \cdot r_W^2 \cdot R_C \cdot C \cdot \ln \frac{T_1 - T_A}{T_0 - T_A} \qquad T_1 = T_w$$

where $T_0 = 0°C$

$$= \pi\ (0.068)^2 \cdot (3.62) \cdot 4{,}184 \cdot 1000\ \ln \frac{5-(-15)}{(0-(-15))}$$

$$= 63{,}296.6 \text{ sec} = 17.58 \text{ hrs.}$$

Safety Factor Time: Replace T_0 with -3°C

$$t_{SF} = \pi\ (0.068)^2 \cdot 3.62 \cdot 4{,}184 \cdot 1000\ \ln \frac{5-(-15)}{(-3-(-15)}$$

$$= 112{,}393.35 \text{ sec} = 31.22 \text{ hrs.}$$

Complete Freezing Time:

$$tF = \pi \cdot r_w^2 . R . L/(T_0 - TA)$$
$$= \pi \cdot (0.068)^2 \cdot 3.62 \cdot 334{,}720 \cdot 1000/(0-(-15))$$
$$= 1{,}173{,}455.7 = 325.96 \text{ hrs.}$$

Example 3:

Determine the Design Freeze Time for two water pipes of inside radius of 38 mm and 76 mm respectively for the following cases:

i) Equal R values (i.e. 50 mm on the 76 mm pipe and 25 mm on the 38 mm pipe).

ii) Equal volumes of insulation on the 76 and 38 mm pipes.

Outside diameters for both the 38 mm and 76 mm pipe are 86 mm and 168 mm respectively.

For both cases, $T_A = -17.8°C$, $T_2 = 4°C$, $L = 3000$ m

Solution:

In both cases assume polyurethane foam insulation with $K = 0.024$ W/m·k and assume $R_C = R_I$.

i) From Figure Q-1(b)

for 76 mm pipe

$$r_I = (168 + 100) \div 2 = 134 \; ; \quad r_p = 168/2 = 84$$

$$R_{76} = \frac{\ln (r_I/r_p)}{2 \pi K_I} = \frac{\ln (134/84)}{2 \pi (0.024)} = 3.00 \text{ m·k/W}$$

for 38 mm pipe

$$r_I = (86 + 50)/2 = 68; \quad r_p = 86/2 = 43$$

$$R_{38} = \frac{\ln (68/43)}{2 \pi (0.024)} = 3.00 \text{ m·K/W}$$

From Figure Q-4:

$$D = r_W^2 \cdot V \cdot C \cdot R = q \cdot C \cdot R$$

say $q = 3.78 \times 10^{-3}$ m³/sec, $C_p = 4,184$ J/kg.K, $\gamma = 1000$ kg/m³

$$D = 3.78 \times 10^{-3} \cdot (4,184) \cdot (1000) \cdot (3.0)$$
$$= 47,447 \text{ m}$$

$$T_1 = T_A + (T_2 - T_A)/\exp(-L/D)$$

since $L/D \leq 0.1$

$$T_1 = T_A + (T_2 - T_A)/(I-L/D)$$
$$= -17.8 + (4-(-17.8)/(1-3000/47,477)$$
$$= 5.47°C$$

$$t_{D76} = r_w^2 \cdot R \cdot C \cdot \ln \frac{T_1 - T_A}{T_0 - T_A}$$

$$= (0.076)^2 \cdot (3.0) \cdot (4,184) \cdot (1000) \cdot \ln \frac{5.47-(-17.8)}{0-(-17.8)}$$

$$= 19,427.7 \text{ sec} = 5.4 \text{ hrs.}$$

$$t_{D38} = (0.038)^2 \cdot (3.0) \cdot (4,184) \cdot (1000) \cdot \ln \frac{5.47-(-17.8)}{0-(-17.8)}$$

$$= 4856.9 \text{ sec} = 1.35 \text{ hrs.}$$

ii) Volume of insulation on 76 mm pipe

$$= \pi \, (r_I^2 - r_p^2) = \pi \, [(134)^2 - (84)^2] = 34,243 \ \frac{\text{mm}^3}{\text{mm}}$$

Volume of insulation on 38 mm pipe

$$= 34,243 \text{ mm}^3/\text{mm}$$

Therefore:

$$\pi \, (r_I^2 - r_p^2) = 34,243$$

$$r_I^2 = \underline{34,243} + r_p^2$$

$$= 10,900 + (43)^2$$

$$r_I = 113 \text{ mm}$$

$$R_{38} = \frac{\ln (113/43)}{2 \pi (0.024)} = 6.4 \text{ m.k/W}$$

New Freeze Time for 38 mm pipe

$$D = q \cdot C \cdot R$$

$$= 3.78 \times 10^{-3} \cdot (4,184) \cdot (1000) \cdot (6.4)$$

$$= 101,219 \text{ mm}$$

$$T_1 = -17.8 + (4-(-17.8))/(1-3000/101,219)$$

$$= 4.7^\circ\text{C}$$

$$T_{D38} = \pi \, (.038)^2 \cdot (6.4) \cdot (4,184) \cdot (1000) \cdot \ln \frac{4.7-(-17.8)}{0-(-17.8)}$$

$$= 28,468.8 \text{ sec.} = 7.9 \text{ hrs.}$$

TABLE I
THERMAL CONDUCTIVITIES OF COMMON MATERIALS

	Unit Weight (dry) kg/m^3	Specific Heat Capacity	Thermal Conductivity W/m.K
Air no convection (0°C)		0.24	0.024
Air film, outside, 24 km/h wind (per air film)			0.86
Air Film, inside (per air film)			0.24
Polyurethane foam	32	0.4	0.024
Polystyrene foam	30	0.3	0.036
Rock wool, glass wool	55	0.2	0.040
Snow, new, loose	85	0.5	0.08
Snow, on ground	300	0.5	0.23
Snow, drifted and compacted	500	0.5	0.7
Ice at -40°C	900	0.5	2.66
Ice at 0°C	900	0.5	2.21
Water (0°C)	1000	1.0	0.58
Peat, dry	250	0.5	0.07
Peat, thawed, 80% moisture	250	0.32	0.14
Peat, frozen, 80% ice	250	0.22	1.73
Peat, pressed, moist	1140	0.4	0.70
Clay, dry	1700	0.42	0.9
Clay, thawed, saturated (20%)	1700	0.42	1.6
Clay, frozen, saturated (20%)	1700	0.32	2.1
Sand, dry	1700	0.19	1.1
Sand, thawed, saturated (10%)	2000	0.29	3.2
Sand, Frozen, saturated (10%)	2000	0.24	4.1
Rock Typical	2500	0.20	2.2
Wood, plywood, dry	600	0.65	0.17
Wood, fir or pine, dry	500	0.6	0.12
Wood, maple, or oak, dry	700	0.5	0.17
Insulating concrete (varies)	200 to 1500		0.07 to 0.60
Concrete	2500	0.16	1.7
Asphalt	200		0.72
Polyethylene, high density	950	0.54	0.36
PVC	1400	0.25	0.19
Asbestos cement	1900		0.65
Wood stave (varies)			0.26
Steel	7500	0.12	43
Ductile Iron	7500		50
Aluminum	2700	0.21	200
Copper	8800	0.1	375

NOTES:

1. Values are representative of materials but most materials have a variation in thermal properties.

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TABLE 2
LIST OF SYMBOLS

List of Symbols

A = Amplitude
A = Thaw factor = T^* arccosh H_p/r_p
$B = \sqrt{\pi \; C_f/k \cdot p}$
$c = \sqrt{H^2 - r^2}$, m (ft)
C = Volumetric heat capacity, Cal/m^3 (BTU/ft^3)
d & t = Thickness, m (ft)
D = Scaling parameter, m (ft)
E = Young's modulus, kg/m^2 (lb/ft^2)
F = arccosh (H/r)
h = Thermal film coefficient (or surface conductance), Cal/h·ft^2·°C (BTU/h·ft^2·°F
H = Depth of bury, m (ft)
I = Freezing or thawing index, °C·h (°F·h)
k = Thermal conductivity, Cal/h·m·°C (BTU/h·ft·°F)
l = Length, m (ft)
L = Latent heat, Cal/m^3 (BTU/ft^3)
p = Period, h
P = Perimeter (mean), m (ft)
q = Heat loss, Cal (BTU)
Q = Rate of heat loss per unit longitudinal length, Cal/m·h (BTU/ft·h)
r = Radius, m (ft)
R = Thermal resistance of unit logitudinal length, h·m·°C/Cal (h·ft·°F/BTU)
t = Time, h
T = Temperature, °C (°F)
$T^* = (T_I - T_0)/(T_0 - T_G)$
u = Coefficient of thermal expansion, m/m·°C (ft/ft·°F)
w = Moisture content by dry weight, %
V = Velocity, m/h (ft/h)
x = Depth
X = Depth to freezing (0°C) plane, m (ft)
α = Thermal diffusivity, m^2/h (ft^2/h)
γ = Unit weight (density), kg/m^3 (lb/ft^3)
a, μ, λ = Coefficients in modified Berggren equation

List of Subscripts

A - refers to Air
C - refers to Conduit
E - refers to Exterior casing (of utilidor)
f - refers to Frozen soil
g - refers to Ground freezing index
G - refers to Ground
h - refers to Heating index
I - refers to Insulation
j - denotes 1,2,3,....
L - refers to Thermal lining (of utilidor)
m - refers to Mean
0 - refers to (Zero) Freezing point of water
P - refers to Pipe
S - refers to Soil
t - refers to Thawed soil
U - refers to Utilidor
W - refers to Water (fluid) within a pipe
x - refers to Depth
Z - refers to Zone of thaw

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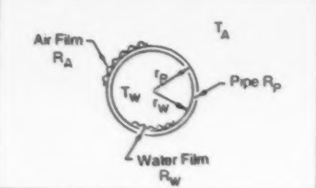
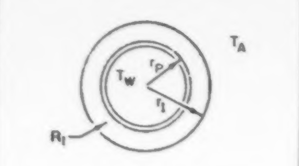
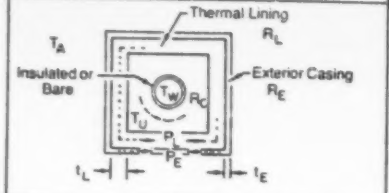
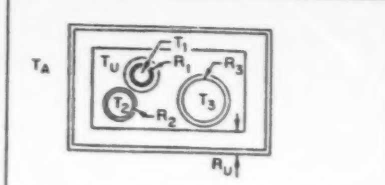
	(a) Bare Pipe	(b) Insulated Pipe	(c) Single Pipe in a Box	(d) Multiple Pipe Utilidor
Sketch	 Air Film R_A T_A r_P Pipe R_P T_W r_W Water Film R_W		 Thermal Lining R_L T_A Insulated or Bare Exterior Casing R_E T_W R_C T_U P_L P_E t_L t_E	 T_A T_1 T_U R_1 R_3 T_2 R_2 T_3 R_U
Assumptions	Thin walled pipe (i.e. $r_P \lesssim 2r_W$). R_W is negligible. $R_P \lesssim R_A$	All thermal resistances but that of the insulation are neglected.	Convection ensures the temperature inside the utilidor, T_U, is uniform. Utilidor air films neglected.	Same as (c).
Thermal Resistance	$R_P = (r_P - r_W)/(r_P + r_W)\pi k_P$ $h_A = N\left(\frac{T_W - T_A}{r_P}\right)^{0.25} W$ $R_A = 1/2\pi r_P h_A$ $R_C = R_P + R_A$ $N = 0.23\,\text{Btu/h}\cdot\text{ft}^{\frac{7}{4}}\cdot{}^\circ\text{F}^{\frac{5}{4}}$ $W = \sqrt{12.5V + 1}$ for V = miles / h $N = 1.12\,\text{J/s}\cdot\text{m}^{\frac{7}{4}}\cdot{}^\circ\text{C}^{\frac{5}{4}}$ $W = \sqrt{0.56V + 1}$ for V = m / s	$R_C = R_I = \frac{\ln(r_I/r_P)}{2\pi k_I}$ $\simeq \left(\frac{r_I - r_P}{r_I + r_P}\right)/\pi k_I$ if $r_I \lesssim 2r_P$ Or given r_I/r_P and k_I; read off R_I from graph	Calculate R_C, the thermal resistance of the interior conduit by: using (b) if insulated or using (a) if bare and replacing T_A in the formula for h_A by an **estimate** for T_U ($\leq T_W$) $R_L = t_L/P_L k_L$ $R_E = t_E/P_E k_E$ $R_U = R_L + R_E$ $R = R_C + R_U$ $T_U = \frac{(T_W/R_C) + (T_A/R_U)}{(1/R_C) + (1/R_U)}$ If bare pipe, iterate T_U	Calculate R for each pipe as in (c) to get R_J, (J = 1, 2, 3, . . .). Calculate R_U as in (c) $T_U = \frac{\sum_J (T_J/R_J) + (T_A/R_U)}{\sum_J (1/R_J) + (1/R_U)}$ If bare pipes present, iterate T_U
Rate of Heat Loss	$Q = (T_W - T_A)/R_C$	$Q = (T_W - T_A)/R_I$	$Q = (T_W - T_A)/R$	$Q_J = (T_J - T_U)/R_J$ (per pipe) $Q = \sum_J Q_J = (T_U - T_A)/R_U$
Insulation Thickness (given Q)	N/A	$r_I - r_P = r_P\{\exp[2\pi k_I(T_W - T_A)/Q] - 1\}$ $\simeq \pi k_I(T_W - T_A)Q$ if $r_I \lesssim 2r_P$ Or given R_I and k_I; read off r_I/r_P from graph	Obtain R_E and R_C as above $t_U = P_L k_L\left[\frac{(T_W - T_A)}{Q} - R_E - R_C\right]$ If bare interior pipe, iterate T_U, R_C and hence t_L	Given acceptable Q_J, calculate R_J as above and evaluate $T_U = T_J - R_J Q_J$ for each pipe for which Q_J is known. Using the maximum T_U found, calculate new Q_J as above. Using these Q_J and the same T_U, evaluate $t_L = P_L k_L\left[\frac{T_U - T_A}{\Sigma Q_J} - R_E\right]$ If bare pipes present, iterate T_U, R_J and hence t_L
Comments	Often, for metal pipes, R_P may be neglected. If R_P is significant, the expression above for h_A will generate an overestimate of Q. If $T_A > T_W$ switch T_A and T_W in the expression for h_A.	The neglected thermal resistances given in (a) may be included if desired. Estimate a value for the insulation surface temperature and calculate h_A and R_A. Interate.	The value of h_A, and hence R_A, is fairly insensitive to the choice of T_U, and so one iteration on T_U is usually sufficient. Often R_E may be neglected. Similar calculational procedure may be performed for pipes and utilidors of different cross-section.	as (c). If it is clear that one pipe dominates the heat loss process, (c) may be used to estimate T_U. It is wise to consider the heat loss from the various pipes if certain other pipes cease to function.

FIGURE Q-1: STEADY-STATE THERMAL EQUATIONS FOR ABOVE-SURFACE PIPES

Reproduced with the permission of the Minister of Supply and Services Canada from "Utilities Delivery in Arctic Region". Environment Canada, Report No. EPS 3-WP-77-1, 1977.

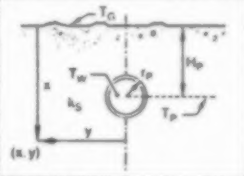
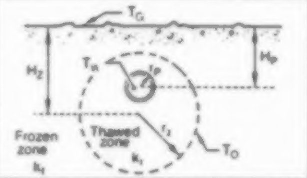
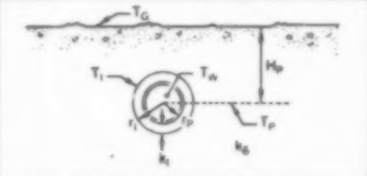
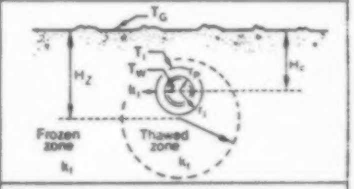
	(a) Bare, No Thaw	(b) Bare, With Thaw Zone	(c) Insulated, No Thaw	(d) Insulated, With Thaw Zone
Sketch	 T_G T_w r_p k_S x y (x, y) H_p T_p	 T_G H_Z T_w r_p H_p Frozen zone k_f Thawed zone k_t r_Z T_O	 T_G T_i T_w H_p r_i r_p T_p k_i k_S	 T_G T_i T_w r_p k_i r_i H_Z H_p Frozen zone k_f Thawed zone k_t
Assumptions	Neglect all thermal resistances except that of the soil.	Same as (a), but accounting for the different conductivities of thawed and frozen soil.	Neglecting all thermal resistances except those of the soil and insulation. Outer surface of insulation assumed to be isothermal. $r_i - r_p \ll H_p$	Same as (c) but accounting for the different thermal conductivities of thawed and frozen soil.
Thermal Resistance and Thaw Zone Parameters	$R_S = \frac{\operatorname{arccosh}(H_p/r_p)}{2\pi k_S}$ $= \frac{\ln[(H_p/r_p) + \sqrt{(H_p/r_p)^2 - 1}]}{2\pi k_S}$ $= \frac{\ln(2H_p/r_p)}{2\pi k_S}$ if $H_p \geq 2r_p$ Or: Given H_p, r_p and k_S; Read off R_S from Figure 15.15	$T_w' = \frac{k_t}{k_f}(T_w - T_O) + T_O$ $T^* = \frac{T_O - T_G}{T_w - T_G}$ $c = \sqrt{H_p^2 - r_p^2} \approx H_p$ if $H_p/r_p \geq 7$ $A = T^* \operatorname{arccosh}(H_p/r_p)$ $= T^* \ln(2H_p/r_p)$ if $H_p \geq 2r_p$ Or: Given H_p/r_p; Read off arccosh (H_p/r_p) from Figure 15.15 $H_Z = c \coth A$ $\quad r_Z = c \operatorname{csch} A$ Or: Given A; Read off H_Z/c and r_Z/c from Figure 15.16 (if $A \geq 0.2$, use $H_Z/c = r_Z/c = 1/A$) R_T, R_F and R_S $(= R_T + R_F)$ as given in (d), but with r_i replaced by r_p.	R_i as given in Figure 15.10 (b) R_S as given in (a), but with r_p replaced by r_i $T_i = T_w - \frac{R_i(T_w - T_G)}{R_S + R_i}$ For known T_w, T_O, and R_S, the minimum insulation thickness to prevent thaw (ie. $T_i = T_O$) is given by: $R_i' = \frac{T_w - T_O}{T_O - T_G} R_S$	R_i as given in Figure 15.10 (b) T_w', T^*, c, H_Z, r_Z and R_S' as in (b) but with r_p replaced by r_i and using: $A = T^*[\operatorname{arccosh}(H_p/r_p) + 2\pi k_f R_i]$ $T_i = T_w - \frac{R_i(T_w' - T_G)}{R_S' + (k_f/k_i)R_i}$ Also: $R_T = [\operatorname{arccosh}(H_p/r_p) - \operatorname{arccosh}(H_Z/r_Z)]/2\pi k_t$ $= [\ln(H_p \cdot r_Z/r_i \cdot H_Z)]/2\pi k_t$ if $H_Z \geq 2r_Z$ $R_F = [\operatorname{arccosh}(H_Z/r_Z)]/2\pi k_f$ $= [\ln(2H_Z/r_Z)]/2\pi k_f$ if $H_Z \geq 2r_Z$ Or: Given H_p/r_i and H_Z/r_Z; Read off arccosh (H_p/r_i) and arccosh (H_Z/r_Z) from Figure 15.15 $R_S = R_T + R_F$
Rate of Heat Loss	$Q = \frac{T_w - T_G}{R_S}$	$Q = \frac{T_w' - T_G}{R_S'}$ where $R_S' = \frac{\operatorname{arccosh}(H_p/r_p)}{2\pi k_f}$ Or: To evaluate R_S' use Figure 15.15	$Q = \frac{T_w - T_G}{R_i + R_S}$	$Q = \frac{T_w' - T_G}{R_S' + (k_f/k_i)R_i}$
Insulation Thickness	N/A	N/A	For no thawing outside the insulation the minimum insulation thickness is given by: $r_i - r_p = r_p[\exp(2\pi k_i R_i') - 1]$ Or: Given R_i and k_i; Read off r_i/r_p from Figure 15.14	Given H_Z or r_Z calculate H_Z/c or r_Z/c and use Figure 15.16 to evaluate A. Then use Figure 15.15 for arccosh (H_p/r_i) $R_i = [(A/T^*) + \operatorname{arccosh}(H_p/r_i)]/2\pi k_f$ $r_i - r_p$ as in (c) but with R_i' replaced by R_i from above
Comments	For practical calculations of heat loss T_G may be replaced by T_p, the undisturbed ground temperature at the pipe axis depth. For an upper limit on heat loss use $k_S = k_t$, otherwise use $k_S = (k_t + k_f)/2$	The thawed zone is a circle in cross-section	May be used to approximate (d) if $k_t \approx k_f$ and/or $r_Z \approx r_i$, and thaw zone parameters are not required. Use $k_S = k_f$ or $k_S = (k_t + k_f)/2$ as in (a).	Often the above expressions for R_T, R_F and R_S are not required

FIGURE Q-2: THERMAL EQUATIONS FOR BELOW SURFACE PIPES

Reproduced with the permission of the Minister of Supply and Services Canada from "Cold Climate Utilities Delivery Design Manual". Environment Canada Report No. EPS 3-WP-79-2, March 1979.

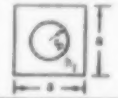
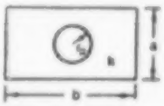
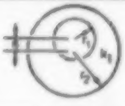
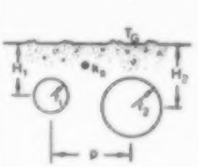
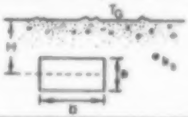
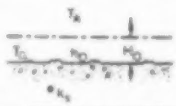
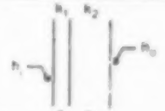
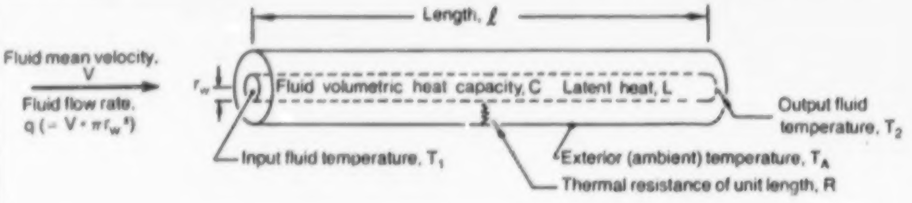
1	Square insulation		$R = \frac{1}{2\pi k_1} \ln 1.08 \frac{a}{2r_1}$
2	Rectangular insulation		$R = \frac{1}{2\pi k} \ln\left(\frac{4a}{\pi r} - 2S\right)$ b/a S b/a S b/a S 1.00 0.08290 2.00 0.00373 4.00 6.97×10^{-6} 1.25 0.03963 2.25 0.00170 5.00 3.01×10^{-7} 1.50 0.01781 2.50 0.00078 ⋮ ⋮ 1.75 0.00816 3.00 0.00016 ∞ 0
3	Eccentric cylindrical insulation		$R = \frac{1}{2\pi k_1} \ln \frac{\sqrt{(r_2+r_1)^2 - e^2} + \sqrt{(r_2-r_1)^2 - e^2}}{\sqrt{(r_2+r_1)^2 - e^2} - \sqrt{(r_2-r_1)^2 - e^2}}$ $= \frac{1}{2\pi k_1} \operatorname{arccosh} \frac{r_1^2 + r_2^2 - e^2}{2r_1 r_2}$
4	Two buried pipes		Where $H_1 \geq 3r_1$, $H_2 \geq 3r_2$ and $p \geq 3(r_1+r_2)$ $R_{1-2} = \frac{1}{2\pi k_s} \cdot \frac{\ln\frac{2H_1}{r_1} \cdot \ln\frac{2H_2}{r_2} - \left[\ln\sqrt{\frac{(h_1+h_2)^2+p^2}{(h_1-h_2)^2+p^2}}\right]^2}{\ln\sqrt{\frac{(h_1+h_2)^2+p^2}{(h_1-h_2)^2+p^2}}}$ $R_{1-T_0} = \frac{1}{2\pi k_s} \cdot \frac{\ln\frac{2H_1}{r_1} \cdot \ln\frac{2H_2}{r_2} - \left[\ln\sqrt{\frac{(h_1+h_2)^2+p^2}{(h_1-h_2)^2+p^2}}\right]^2}{\ln\frac{2H_2}{r_1} - \ln\sqrt{\frac{(h_1+h_2)^2+p^2}{(h_1-h_2)^2+p^2}}}$
5	Buried rectangular duct		$R = \frac{1}{k_s\left(5.7 + \frac{b}{2a}\right)} \ln \frac{3.5H}{b^{0.25} \cdot a^{0.75}}$
6	Surface thermal resistance		Surface thermal resistance between ground and air can be approximately estimated as the equivalent thickness of the underlying soil equal to $H_0 = \frac{k_s}{h_0}$
7	Composite wall		$R = \frac{1}{h_i} + \frac{1}{h_0} + \frac{x_1}{k_1} + \frac{x_2}{k_2}$

FIGURE Q-3: THERMAL RESISTANCE OF VARIOUS SHAPES AND BODIES

Figure Q-3 is taken from:
Goodrich, L.E. "Computer Simulations", Appendix to Thermal Conditions in Permafrost - A Review of North American Literature" by Gold, L.W. and Lachenbruch, A.H., in: North American Contribution Permafrost Second International Conference, July 13-28, 1973, Uakutsk, USSR, National Academy of Science, Washington, D.C., pp. 23-25, 1973.

Heat Loss and Temperature Drop in a Fluid Flowing Through a Pipe

Freeze-Up Time For a Full Pipe Under No-Flow Conditions ($V = o$)


Length, ℓ
Fluid mean velocity, V
Fluid flow rate, $q\ (= V \cdot \pi r_w^2)$
r_w
Fluid volumetric heat capacity, C
Latent heat, L
Output fluid temperature, T_2
Input fluid temperature, T_1
Exterior (ambient) temperature, T_A
Thermal resistance of unit length, R

Comments: The above sketch is schematic. R and T_A appearing in these equations can be replaced by the thermal resistance and corresponding exterior temperature for any shape or configuration.

$D = \pi r_w^2\ V \cdot C \cdot R$

Calculate T_1 or T_2, Given R, T_1 or T_2, T_A

$T_1 = T_A + (T_2 - T_A) / \exp(-\ell/D)$

$\quad = T_A + (T_2 - T_A)/(1 - \ell/D) \quad \text{if } \ell/D \le 0.1$

$T_2 = T_A + (T_1 - T_A) \exp(-\ell/D)$

Calculate R, Given T_1, T_2, T_A

$R = -\ell / \pi r_w^2 \cdot V \cdot C \cdot \ln[(T_2 - T_A)/(T_1 - T_A)]$

$\quad = -\ell(T_1 - T_A) / \pi r_w^2 \cdot V \cdot C\ (T_1 - T_2) \text{ if } \ell/D \ge 0.1$

Calculate V, Given T_1, T_2, T_A, R

$V = \ell / \pi r_w^2 \cdot R \cdot C \cdot \ln[(T_2 - T_A)/(T_1 - T_A)]$

$\quad = \ell(T_1 - T_A) / \pi r_w^2 \cdot R \cdot C(T_1 - T_2) \quad \text{if } \ell/D \ge 0.1$

Calculate Heat Loss (Q), Given T_1 or T_2, T_A, V, R

$Q = (D/R)(T_1 - T_A)[1 - \exp(-\ell/D)]$

$\quad = (\ell/R)(T_1 - T_A) \quad \text{for } \ell/D \ge 0.1$

$\quad = D/R\ (T_2 - T_A)\left[\exp(\ell/D) - 1\right]$

Calculate Friction Heating, Given V, f

$Q_f = F \cdot r_w^2 \cdot V \cdot f$

Where:
Q_f = BTU / h · ft
F = 0.2515 BTU / ft^4
r = ft
V = ft / h
f = friction head loss, ft / ft length
Not significant for $V \ge 2.3 \times 10^4$ ft / h

or
Q_f = J / s · m
F = 3.074×10^4 J / m^4
r = m
V = m / s
f = friction head loss, m / m length
Not significant for $V \ge 2$ m / s

Freeze-Up Times; Given R, T_1, T_A

Assume that thermal resistance of the ice, as it forms, and the heat capacity of the pipe and insulation are negligible.

Design Time (Recommended)

t_D = Time for the fluid temperature to drop to the freezing point.

$\quad = \pi \cdot r_w^2 \cdot R \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

$\quad = \pi \cdot r_w^2 \cdot R \cdot C\ [(T_1 - T_O)/(T_1 - T_A)]$

$\qquad \text{for } [(T_1 - T_O)/(T_1 - T_A)] \le 0.1$

$\qquad \text{or } T_1 \ge 0.11\ T_A \text{ (in °C)}$

Safety Factor Time

t_{SF} = Time for the fluid to drop to the nucleation temperature. Same as t_D but with T_O replaced by −3°C.

Complete Freezing Time

t_F = Time for the fluid at freezing point, 0°C to completely freeze solid.

$\quad = \pi \cdot r_w^2 \cdot R \cdot L / (T_O - T_A)$

Calculate R, Given a No-Flow Time

Design Choice

$R_D = \text{time} / \pi \cdot r_w^2 \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

Minimum Resistance

R_{SF} = same as R_D but with T_O replaced by −3°C.

FIGURE Q-4: TEMPERATURE DROP AND FREEZE-UP TIME IN PIPES

Reproduced with the permission of the Minister of Supply and Services Canada from "Utilities Delivery in Arctic Region". Environment Canada, Report No. EPS 3-WP-77-1, 1977.

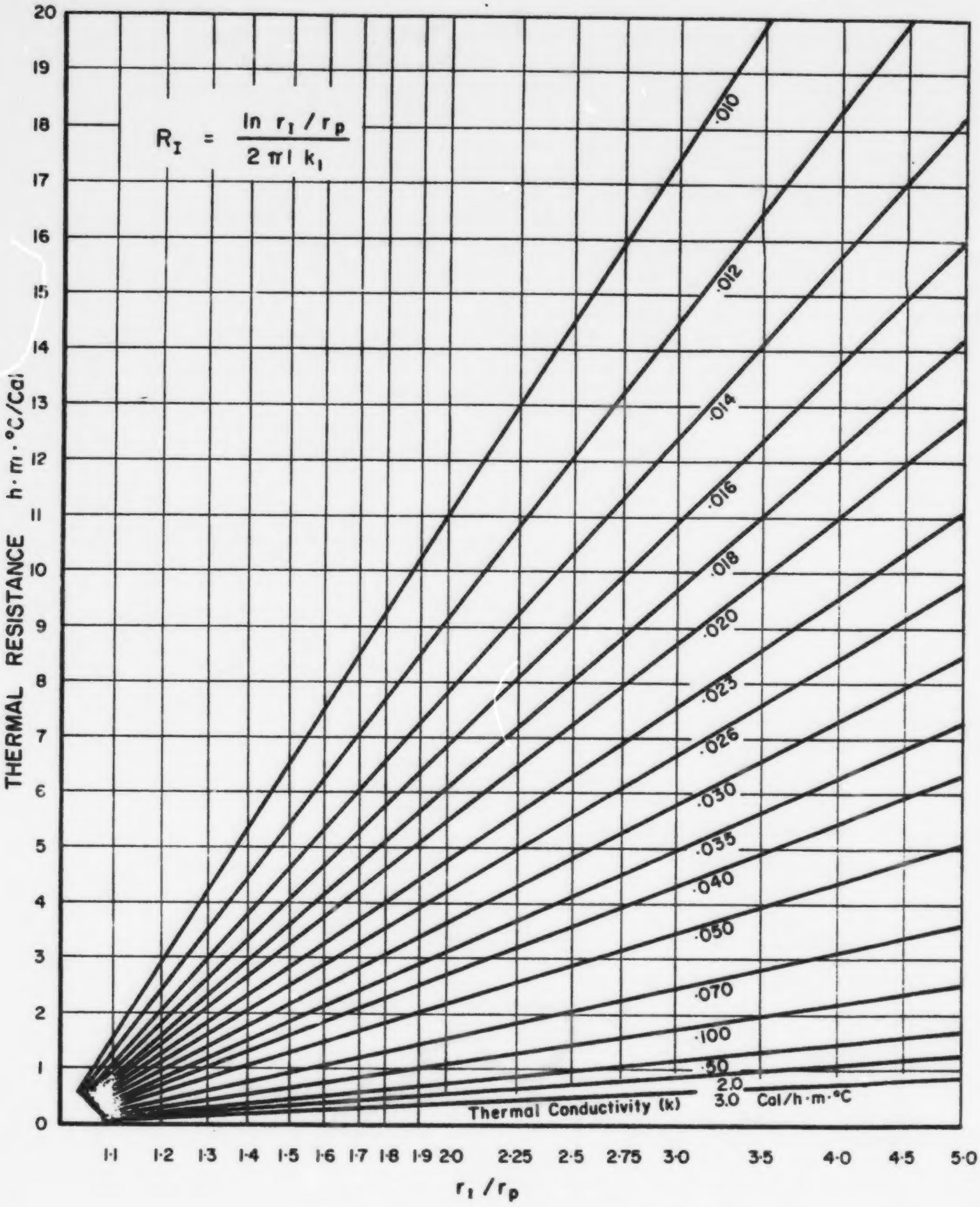


FIGURE Q-5: THERMAL RESISTANCE OF A HOLLOW CYLINDER

Reproduced with the permission of the Minister of Supply and Services Canada from "Cold Climate Utilities Delivery Design Manual", Environment Canada Report No. EPS 3-WP-79-2, March 1979.

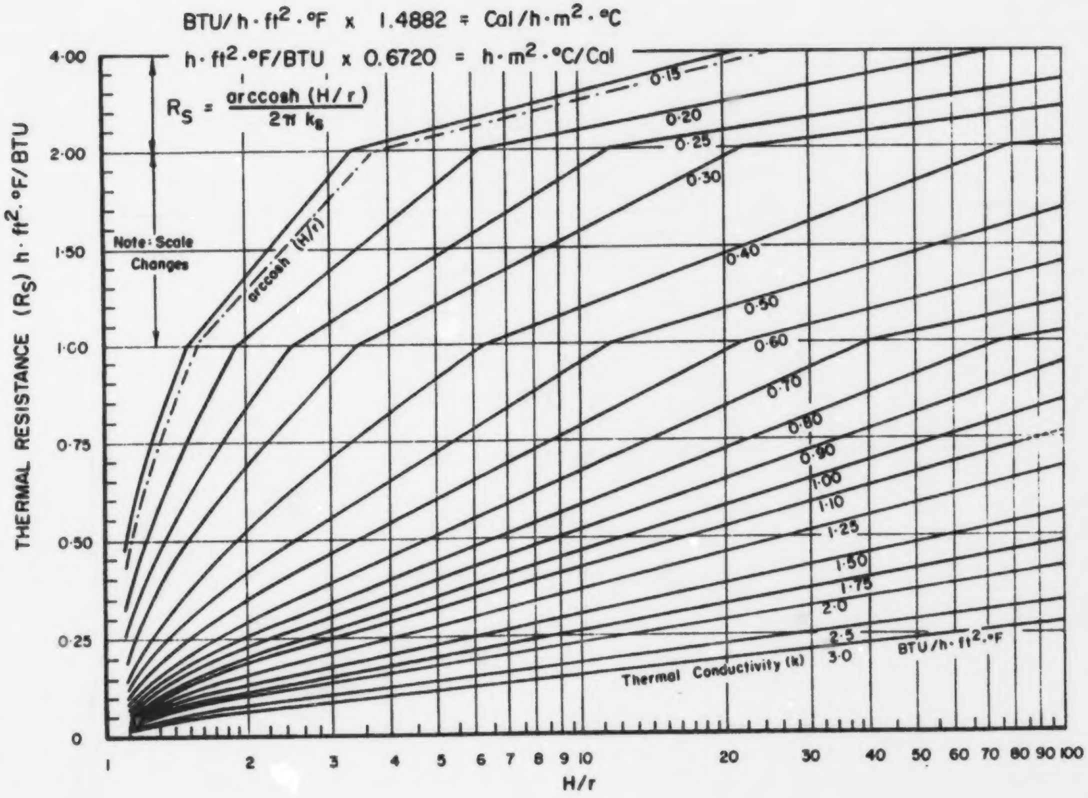


FIGURE Q-6: THERMAL RESISTANCE OF A SOIL MASS COVERING A PIPE

Reproduced with the permission of the Minister of Supply and Serivces Canada from "Cold Climate Utilities Delivery Design Manual", Environment Canada Report No. EPS 3-WP-79-2, March 1979.

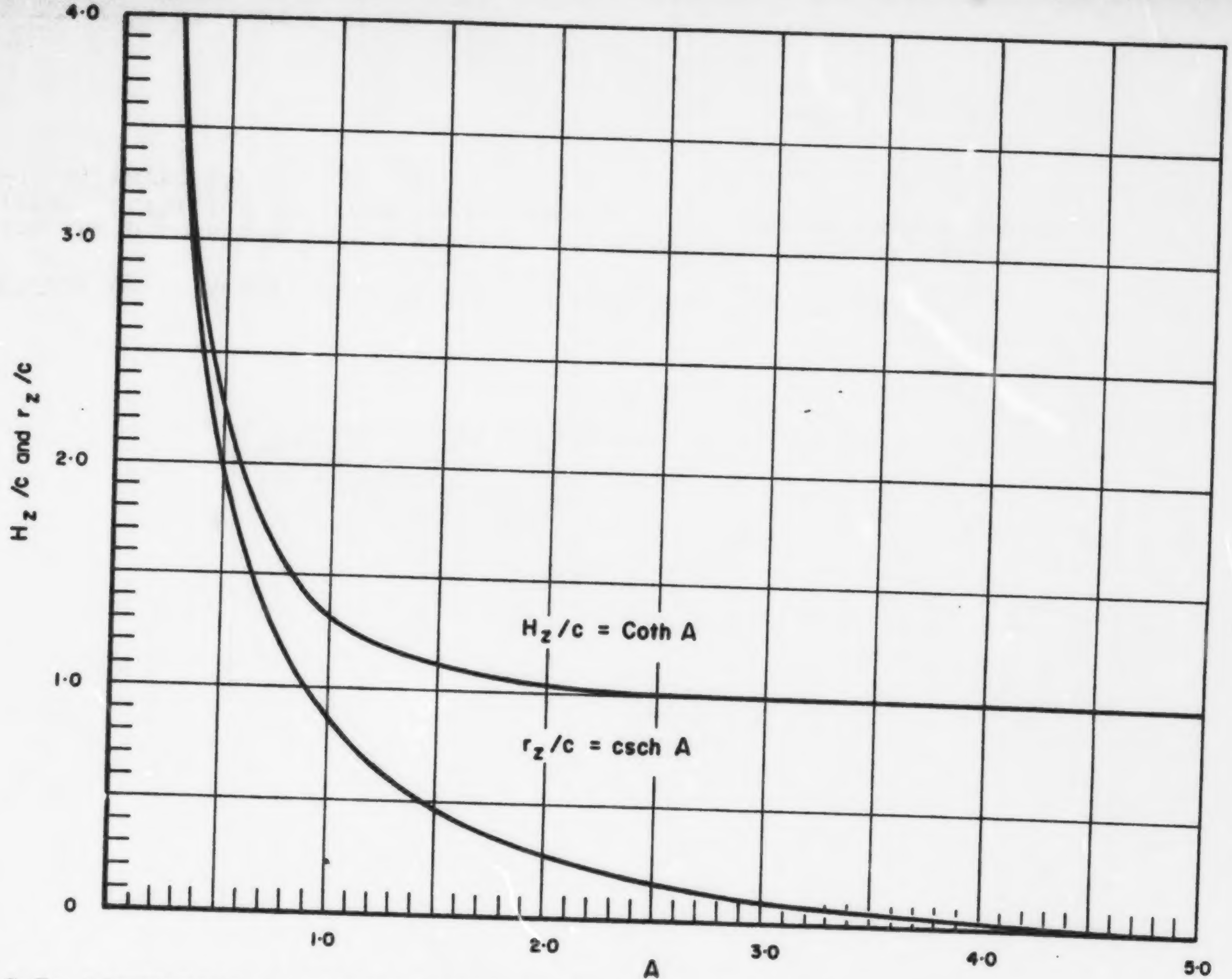


FIGURE Q-7: DIMENSIONS OF A THAW CYLINDER AROUND A PIPE BURIED IN PERMAFROST

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APPENDIX R

PRESSURE SEWER SYSTEM DESIGN FLOWS

(A) GRINDER PUMP (GP) SYSTEMS

Semi-Positive Displacement/Progressive Cavity Pumps

As show in Figure 4-19 of the "Guidelines for Servicing in Areas Subject to Adverse Conditions", this type of GP pump has a nearly vertical H-Q curve. The capacity of the pump varies from 1.01 L/s at O/m TDH to 0.69 L/s at 24.7 m TDH (design head). The unit is capable of operating at heads of up to 40% above the design head.

For the purposes of design, it is assumed that each pump operating discharges 0.69 L/s and that the number of pumps operating simultaneously on any branch or mainline (i.e., the branch or mainline under consideration) will be in accordance with Table I.

A "Typical Semi-Positive Displacement Grinder Pump Design Sheet" together with the recommended design procedures, is shown on page R-3.

TABLE I

TOTAL NUMBER OF GRINDER PUMP CORES CONNECTED TO BRANCH(S)	NUMBER OF GRINDER PUMP CORES OPERATING SIMULTANEOUSLY
1	1
2- 3	2
4- 9	3
10- 18	4
19- 30	5
31- 50	6
51- 80	7
81- 113	8
114- 146	9
147- 179	10
180- 212	11
213- 245	12
246- 278	13
279- 311	14
312- 344	15

NOTE: The above table is based upon data taken from "Design Handbook for Low Pressure Sewer System - Third Edition", Courtesy Environment One Corporation

TYPICAL PRESSURE SEWER DESIGN SHEET

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Br. No.	No. of Pumps	Accum. Total	Max. On	Max. Flow (L/s)	Size (actual ID)	Max. Vel. (m/s)	Length (m)	Friction Loss m/ 100 m.	Friction Loss (Total)	Accum. Head-Loss (m)	Max. Elv. Main (m)	Pump Site Elv. (m)	Elev. Diff. (m)	Max. Total Head (m)

Record the branch number in column (1), the number of Grinder Pump cores connected to each branch section in column (2), and the length of the branch section in column (8). Progressively, add the number of pump cores recorded in column (2) to deter mine the accumulated total for each branch or combination of branches and record in column (3).

Refer to Table No. I to determine the most advantageous division points for branch sections and for the anticipated maximum number of pumps expected to be operating versus the accumulated number installed. Record in column (4).

The output of each Grinder Pump will vary slightly with head; but, under the most severe conditions, **the flow is 0.69 L/s.** Calculate the maximum flow for each run and record in column (5). Select pipe size and record in column (6). Determine the maximum velocities for the pipe type and actual I.D. selected and for the applicable number of Grinder Pumps. Record velocity in column (7).

Determine branch headloss (m/100m) utilizing the actual I.D. of the material to be used and the maximum number of Grinder Pumps (column 4) and record in column (9).

Multiply column (8) by column (9) and divide by 100 to obtain total friction headloss (column 10) for each section of pipe.

Starting at the discharge point, progressively add the individual branch section friction losses as determined in column (10) and record in column (11).

In column (12) record the maximum line elevation between point of discharge and the point under consideration. In column (13) record the elevation of the point under consideration. Subtract column (13) from column (12) and record only positive elevation differentials in column (14). Add column (14) to column (11) and record in column (15) which will show the maximum combination of friction and static head a pump will experience.

Couresty Environment One Corporation

Centrifugal Pumps

As shown in Figure 4-19 of the "Guidelines for Servicing in Areas Subject to Adverse Conditions", a centrifugal grinder pump has an H-Q curve similar to that of any centrifugal pump. Depending upon the individual manufacturer of such units and the size of the pump, the discharge capacity of the unit varies over a much wider range than does a semi-positive displacement/progressive cavity pump. In a typical domestic installation, the "design" discharge rate of such a unit is generally in the order of 1.0 L/s.

For the purposes of the design of a pressure sewer system employing centrifugal pumps, the following Table II should be utilized.

TABLE II

NUMBER OF GP UNITS CONNECTED	SUGGESTED DESIGN FLOW (L/s) AT		
	190 L/c.d	233 L/c.d	284 L/c.d
1	0.95	0.95	0.95
5	1.6	1.6	1.6
10			
20	2.84	2.84	2.84
30			
40			
50	2.84	2.84	3.15
60			
70			
80	3.15	3.78	4.73
90			
100	3.78	4.42	5.68
110			
120	4.1	5.05	6.62
130			
140	4.42	5.68	7.57
150			
160	5.05	6.31	8.52
170			
180	5.68	6.94	9.46
190			
200	6.31	7.57	10.41
210			
220			
230	6.94	8.52	11.98
240			
250			
260	7.57	9.46	13.25
270			
280			
290			
300	8.83	10.72	15.14

NOTES:

1. Intermediate values should be interpolated as necessary.
2. Table II based on Water and Sewage Works - Reference Number 1979 after L.J. Flanegan & C.A. Cadmik.

The design procedure is as shown in the "Typical Pressure Sewer Design Sheet".

(B) SEPTIC TANK EFFLUENT PUMPING (STEP) SYSTEMS

Two of the alternate arrangements for STEP systems are shown in Figures 4-17 and 4-18. By far, the most common installation is that show in Figure 4-18 in the Province of Saskatchewan where units have been installed since 1963. Similar systems are being installed in Manitoba.

The design procedure used for a "Saskatchewan" type STEP system is extremely simple and is shown in Table III. It must be remembered however that the pumps are small and hence have limited TDH. Therefore, it is most likely that its application will be limited in Ontario to service areas which have little of any topographic relief.

TABLE III

MAXIMUM NUMBER OF CONNECTIONS	MINIMUM PIPE SIZE	MAXIMUM LENGTH OF PIPE (m)
40	NPS-2	1525
70	NPS-3	2745
120	NPS-4	No maximum recommended as generally not applicable

An alternate design procedure being employed in the USA for STEP systems closely approximates that used in the design of GP systems. The suggested design flows etc. are shown in Table IV.

TABLE IV

NO. OF DWELLINGS	SUGGESTED DESIGN FLOW (L/s)
1	0.947
5	1.58
10	
20	2.84
30	
40	
50	2.84
60	
70	
80	4.10
90	
100	4.73
110	
120	5.68
130	
140	6.31
150	
160	7.25
170	
180	7.89
190	
200	8.83
210	
220	
230	10.09
240	
250	
260	11.04
270	
280	
290	
300	12.62

NOTES:

1. Suggested design flows based on an average flow of 946 L/dwelling.
2. Intermediate values should be interpolated.
3. Table IV based on Journal WPCF Volume 55, Number 7 after D.J. Tollefsen and R.F. Kelly.

Section 4.6.4.4 of the "Guidelines for Servicing in Areas Subject to Adverse Conditions" notes certain fundamental concepts respecting the design of pressure sewer systems which must be accepted. On occasion, it may be tempting to arbitrarily increase the size of pipe as a "safety factor" or to allow for "unforeseen circumstances. This temptation should be avoided as such arbitrary size increases will generally result in negative operations and maintenance experience. Of specific concern will be the increased solids deposition and/or grease accumulations in the pipe due to inadequate velocity conditions (i.e., increased maintenance) and the increased potential for odours due to increased residence time (operation).

Concern has been expressed that a pressure sewer system does not lend itself to future growth in the same way that a gravity system does and this is, in part, true particularly in considering the aforementioned items. However, experience has shown that a careful initial design will facilitate most future growth conditions while meeting the basic concepts, but is dependent on such factors as topography, percent of future growth in design, location of future growth relative to the initial system, etc.

The fact that in certain circumstances the initial system may not be able to accommodate all future growth without some duplication/paralleling should not necessarily be viewed as negative. In fact, a number of "hidden" advantages may, make this alternative more attractive. These include:

a) Freedom for the designer in site layout of new development;

b) Reduced initial or front-end oversizing costs as the services are only provided as the development occurs;

c) The smaller parallel lines can be readily installed if provision has been made;

d) Community disturbance and environmental damage is minimized.

As a final point it must be noted that it is imperative that the designer of a low pressure sewer system ensure that the actual diameter (I.D.) of the proposed piping material be used in the hydraulic design not the nominal diameter. A review of the manufacturing specifications for the various pipe materials, particularly the thermoplastics (i.e. HDPE, PVC, etc.) which are generally used in the construction of a low pressure sewer system will reveal that there can be significant difference between the actual I.D. and the nominal diameter.

APPENDIX S

ALTERNATE TECHNOLOGIES

GENERAL

In accordance with the general Ontario Government principle to promote and encourage alternative and innovative technology, the Ministry of the Environment will permit, and in some cases encourage, the use of alternate technologies where circumstances warrant.

Applications for approval of proposals employing alternative or innovative technologies should be completed in accordance with the Ministry's publications entitled:

a) A Guide on Applying for the Approval of Sewage Works;
b) A Guide on Applying for the Approval of Water Works.

ALTERNATE TECHNOLOGY ASSESSMENT

Any consideration of an alternate technology such as pressure sewers, vacuum sewers, shallow buried piping systems etc. should be accompanied by a detailed cost-effective analysis with more conventional methods of servicing. A preliminary/cursory evaluation can, in many instances, result in a decision which, upon final design, is not valid. This analysis should consider such factors as capital, operating and maintenance costs but not necessarily be limited to same. As a general guide in this respect, the following factors should be considered.

Pressure and Vacuum Sewer Systems

a) Will the required unit be located inside or outside of the serviced building?

b) Is the existing hydro service to the building adequate or must it me upgraded in order to permit powering of the pumping unit (pressure sewers only)?

c) The life expectancy of the unit.

d) In the case of servicing of existing communities, what is the opinion of the homeowner?

e) Who will be responsible for routine servicing and maintenance of the individual units?

f) Will easements be obtainable from individual property owners to permit the construction of the facilities on private property and to facilitate access for routine servicing and maintenance?

Normally, the Ministry will encourage the municipality in which the works are to be constructed to assume responsibility for the routine servicing and maintenance of the entire system, including the individual units. This service can be provided either directly through municipal works staff or via a service contract executed between the municipality and a local service representative such as a plumbing/mechanical contractor. Alternatively, the Ministry will consider applications where the municipality is responsible for operation and maintenance of those works installed within the public right-of-way with service/maintenance of the works/unit installed on private property being the responsibility of the property owner.

Where the municipality intends to assume full responsibility for operation/maintenance, the municipality should provide suitable indication that it has either:

i) Adequately trained personnel on staff; or,
ii) A service/maintenance agreement with a local contractor who has adequately trained personnel for the required repair and maintenance of the units.

Where the municipality intends to assume responsibility for a service/maintenance of the individual units installed on private property, it should be aware that:

i) By-laws may be required to permit entry to private property for the purposes of servicing and maintenance;
ii) An easement agreement may be necessary between the municipality and/or its agent and the property owner respecting access to private property for the purposes of service and maintenance of the units. Such easement agreements should be registered against title of the property to ensure that any future owner of the property is aware of the easement and the service/maintenance responsibility.

Where the individual homeowner is to be responsible for maintenance of his unit, the proponent should satisfy the Ministry that a qualified maintenance contractor is readily available; that the contractor has been adequately trained in the service and maintenance of the units; that the contractor is in possession of an adequate supply of spare parts etc. and that the homeowner has been advised of the contractor's name, address and telephone number.

It is recommended that the individual units be installed outside and preferably adjacent to the existing building sewer. If the municipality permits the units to be located inside the service building, the following factors should be considered:

i) The owner of the home or building in which the unit will be installed should be in agreement with the proposed location and it should be clearly understood that such a location may inhibit emergency servicing of the unit when maintenance personnel cannot readily gain access to the premises;

ii) The municipality and/or operating authority should accept the responsibility for entering private homes and buildings for the purposes of routine servicing and/or emergency servicing.

Service connections on a pressure sewer sys em should be equipped with a shut-off valve at the lot line, complete with an appropriate operating extension to grade. The individual pumping units should be equipped with audio-visual alarms located inside and outside of the serviced buildings in order to facilitate indication of a pump unit failure.

Where power for the individual units is supplied by a "centralized" source rather than the individual homeowner's hydro service, the unit should be equipped with an elapsed time meter in order to facilitate determination of misuse of the unit via such things as illegal foundation drainage connections etc.

APPENDIX T

CRITERIA FOR PUMPING

TESTS FOR SMALL COMMUNAL GROUND-WATER SUPPLIES

Pumping tests are a basic means of determining the adequacy of a well to supply water at a required rate and of suitable quality, and to anticipate possible interference with water levels in nearby wells. There are a variety of methods and equipment that can be used in pumping tests, depending on the type of hydrologic data required and the ultimate purpose and productivity of the well. It is because of this variety of methods that the following set of basic criteria are deemed necessary. The recommended criteria are intended to provide a basic, uniform set of standards that the MOE deems acceptable whenever the Ministry is involved in approving water supply systems under the following conditions:

- a Certificate of Approval, under s.23 of the Ontario Water Resources Act, is required for small communal or seasonal supplies; and
- a pumping test is used as a method of determining the adequacy of ground water for small communal or seasonal supplies.

The key factor in the above conditions is that the pumping test is used to determine the adequacy of supplies for small communal or seasonal systems. For the purposes of this appendix, a small (or seasonal) water supply system or "minor" water supply system is defined as one which is designed to serve a population equivalent of less than 500 persons.

The need for a distinction between pumping tests for small/minor systems and for large communal systems is based primarily on economic and practical considerations.

The exploration for, and the development of, large supplies is usually much more difficult and costly than might be for supplies for 500 persons or less, and the testing for large supplies usually requires a rigorous pumping test in which there is little allowance for variability from established methods. However, small supplies, such as might be required for up to 500 people, involve relatively low well yields and these yields may be ensured with much less rigorous testing. It may be that in some of these cases traditional methods of testing may be modified to recognize practical and economic limitations without sacrificing the correctness of the results. However, a pumping test even for small supplies, if and when it is carried out, should be based on sound hydrogeologic principles and should readily yield data that can be used to determine the (projected) long-term yield and water quality of a well. In addition, data from the pumping test should allow an evaluation of the likely interference with water levels in existing, nearby wells.

It is a basic assumption that any pumping test be carried out under the guidance of, and analysed by, a qualified hydrogeologist. This is to ensure that proper procedures are followed in order to get accurate, meaningful hydrologic data, and that complex hydrogeologic situations, if and when they arise, are recognized and dealt with expediently.

The following criteria for pumping tests for small communal water supplies are considered basic, with additions (at the discretion of the Ministry hydrogeologist) as necessary.

(1) A pump should be used; the use of a bailer is generally not acceptable.

(2) The rate of pumping should be at, or in excess of, the maximum anticipated production rate; a constant rate should be maintained throughout the test.

(3) Pumping tests should be long enough to get the coefficient of transmissibility (and the coefficient of storage), and to demonstrate the long-term yield of the well. This usually requires that the test be long enough for the slope of the drawdown-time (or distance) curves to become uniform. Wells in a multiple well system should be pumped concurrently.

(4) In an area of known or suspected poor ground water quality (or surface water in case of induced infiltration wells), the duration of the pumping test should be long enough to be able to determine, with reasonable assurance, that the water quality in the pumped well has stabilized. This necessitates water sampling during the pumping test. Water quality parameters to be analyzed for should be determined in consultation with the Ministry's Regional Office staff.

(5) It is recommended that the drawdown (interference) cone be established during the pumping test. This would involve the measurement

of water levels in representative, nearby wells prior to, during, and at the end of a pumping test to determine the extent and amount of water level interference.